FIG. 1

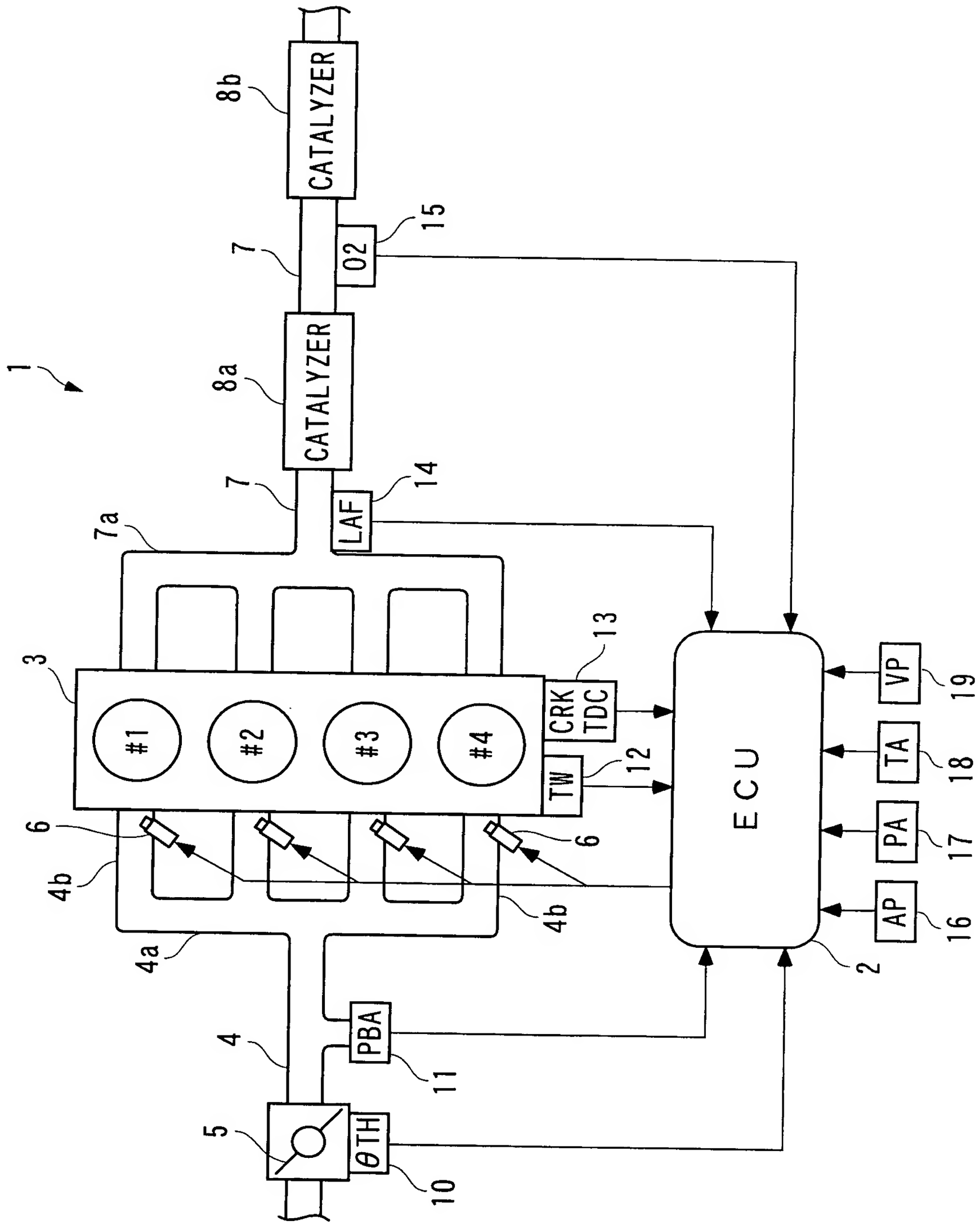

1
2
3
4
4a
4b
5
6
7
7a
8a
8b
10
11
12
13
14
15
16
17
18
19
CATALYZER
CATALYZER
O2
LAF
PBA
θTH
CRK
TDC
TW
#1
#2
#3
#4
ECU
AP
PA
TA
VP

FIG. 2

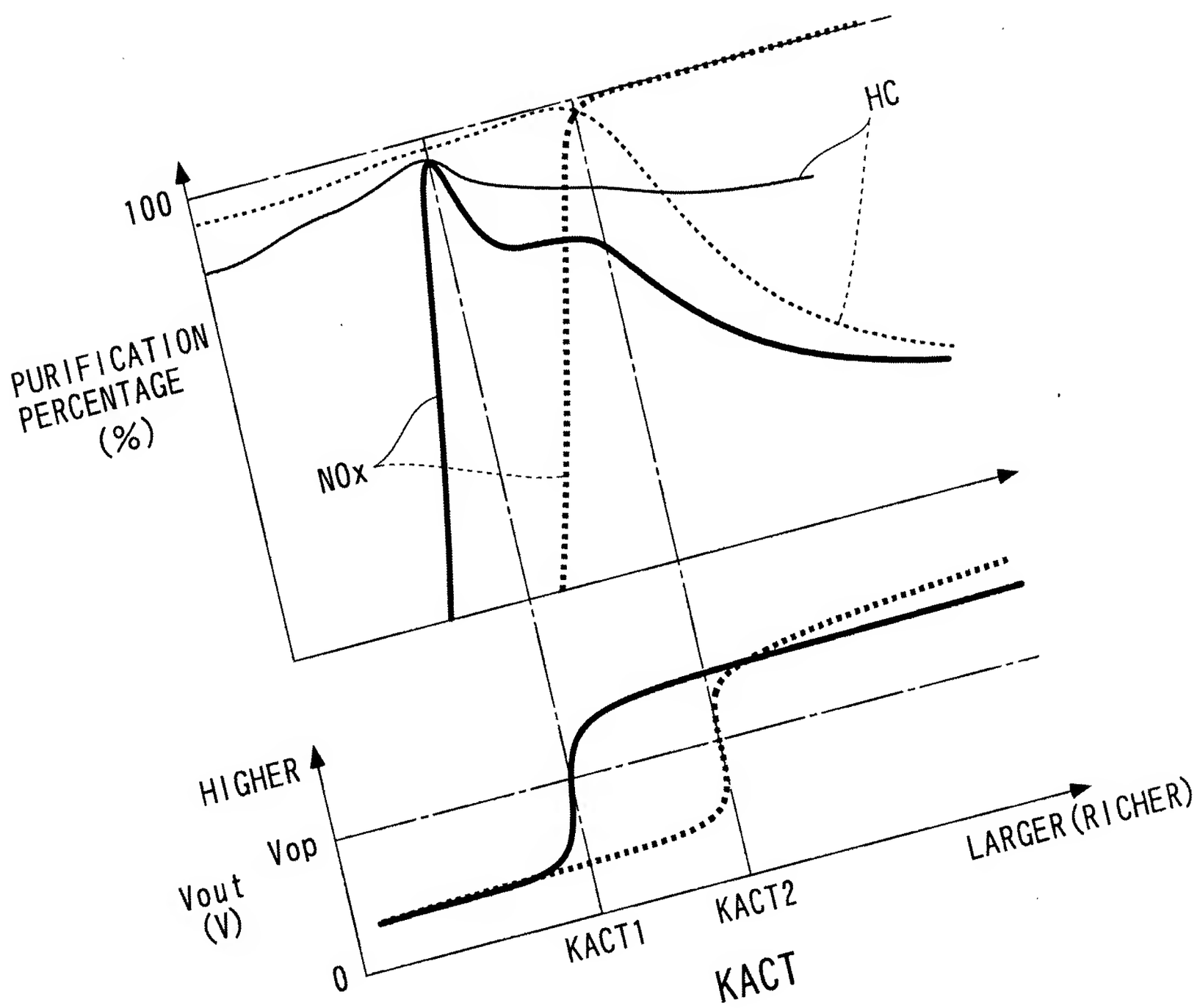

HC
100
PURIFICATION PERCENTAGE (%)
NOx
HIGHER
Vop
Vout (V)
0
KACT1
KACT2
LARGER (RICHER)
KACT

FIG. 3

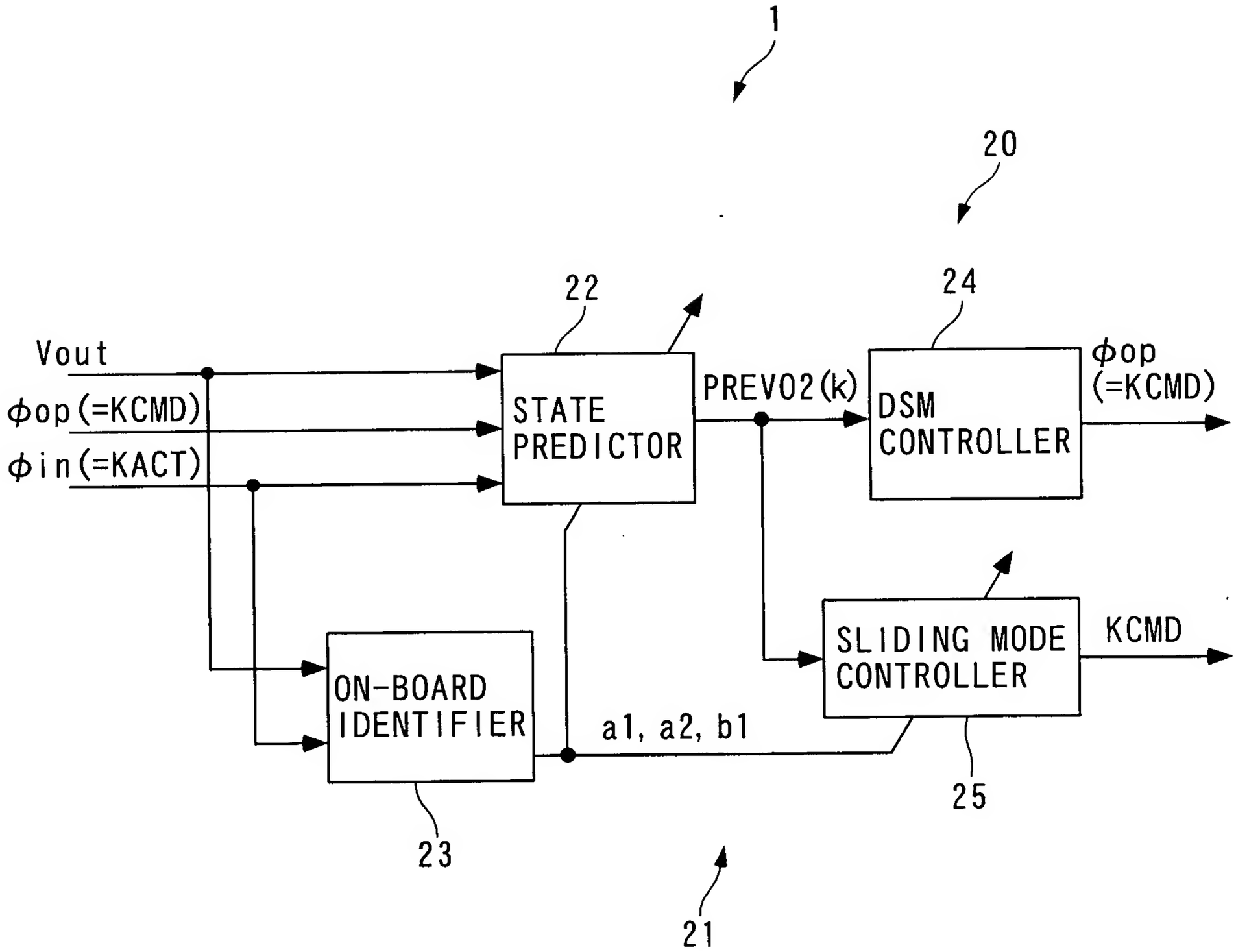

1
20
22
24
Vout
φop(=KCMD)
φin(=KACT)
STATE PREDICTOR
PREV02(k)
DSM CONTROLLER
φop (=KCMD)
SLIDING MODE CONTROLLER
KCMD
ON-BOARD IDENTIFIER
a1, a2, b1
23
25
21

FIG. 4

$$A=\begin{bmatrix} a1 & a2 \\ 1 & 0 \end{bmatrix} \quad \cdots\cdots (4)$$

$$B=\begin{bmatrix} b1 \\ 0 \end{bmatrix} \quad \cdots\cdots (5)$$

$$PREVO2(k)=\alpha 1\cdot VO2(k)+\alpha 2\cdot VO2(k-1)+\sum_{i=1}^{dt}\beta i\cdot DKCMD(k-i) \quad \cdots\cdots (6)$$

Where $\alpha 1$:One-row, one-column element of A^{dt};
$\alpha 2$:One-row, two-column element of A^{dt}; and
βi :One-row element of $A^{i-1}B$.

$$PREVO2(k)=\alpha 1\cdot VO2(k)+\alpha 2\cdot VO2(k-1)+\sum_{i=1}^{d'-1}\beta i\cdot DKCMD(k-i)+\sum_{j=d'}^{dt}\beta j\cdot DKACT(k-j) \quad \cdots\cdots (7)$$

Where βj :One-row element of $A^{j-1}B$.

FIG. 5

$$\theta(k)=\theta(k-1)+KP(k)\cdot ide\_f(k) \quad \cdots\cdots (8)$$

$$\theta(k)^T=[a1'(k),\ a2'(k),\ b1'(k)] \quad \cdots\cdots (9)$$

$$ide\_f(k)=\frac{1}{n}\sum_{i=1}^{n} ide(i) \quad \cdots\cdots (10)$$

$$ide(k)=VO2(k)-VO2HAT(k) \quad \cdots\cdots (11)$$

$$VO2HAT(k)=\theta(k-1)^T\zeta(k) \quad \cdots\cdots (12)$$

$$\zeta(k)^T=[VO2(k-1),\ VO2(k-2),\ DKACT(k-d-dd)] \quad \cdots\cdots (13)$$

$$KP(k)=\frac{P(k)\ \zeta(k)}{1+\zeta(k)^T\ P(k)\ \zeta(k)} \quad \cdots\cdots (14)$$

$$P(k+1)=\frac{1}{\lambda_1}\left(I-\frac{\lambda_2 P(k)\ \zeta(k)\ \zeta(k)^T}{\lambda_1+\lambda_2\ \zeta(k)^T\ P(k)\ \zeta(k)}\right)P(k) \quad \cdots\cdots (15)$$

Where I is a unit matrix

FIG. 6

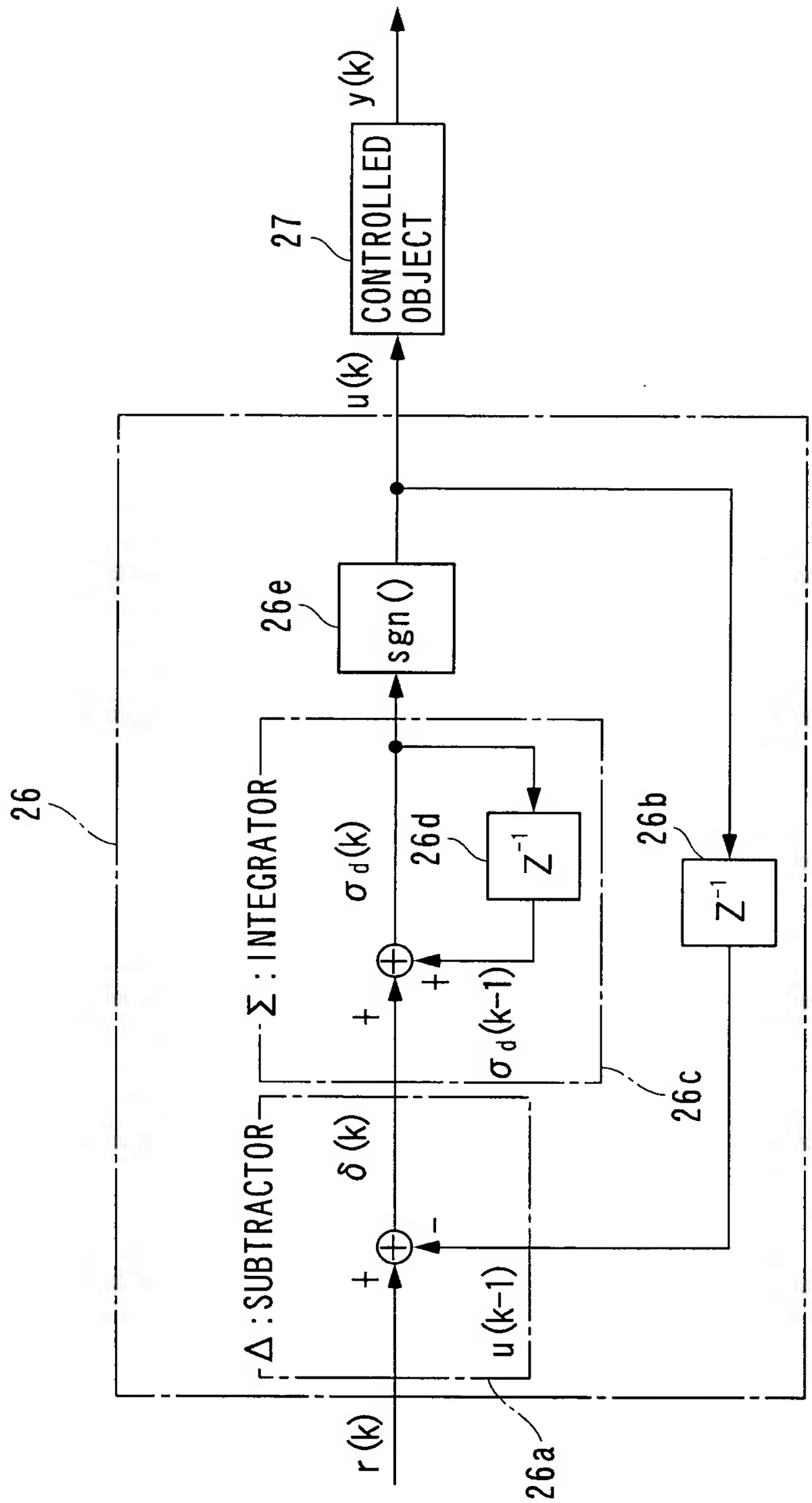

y(k)
27
CONTROLLED OBJECT
u(k)
26
26e
sgn ()
Σ : INTEGRATOR
σd(k)
26d
Z-1
+
+
σd(k-1)
26b
Z-1
26c
Δ : SUBTRACTOR
δ (k)
+
-
u(k-1)
r (k)
26a

FIG. 7

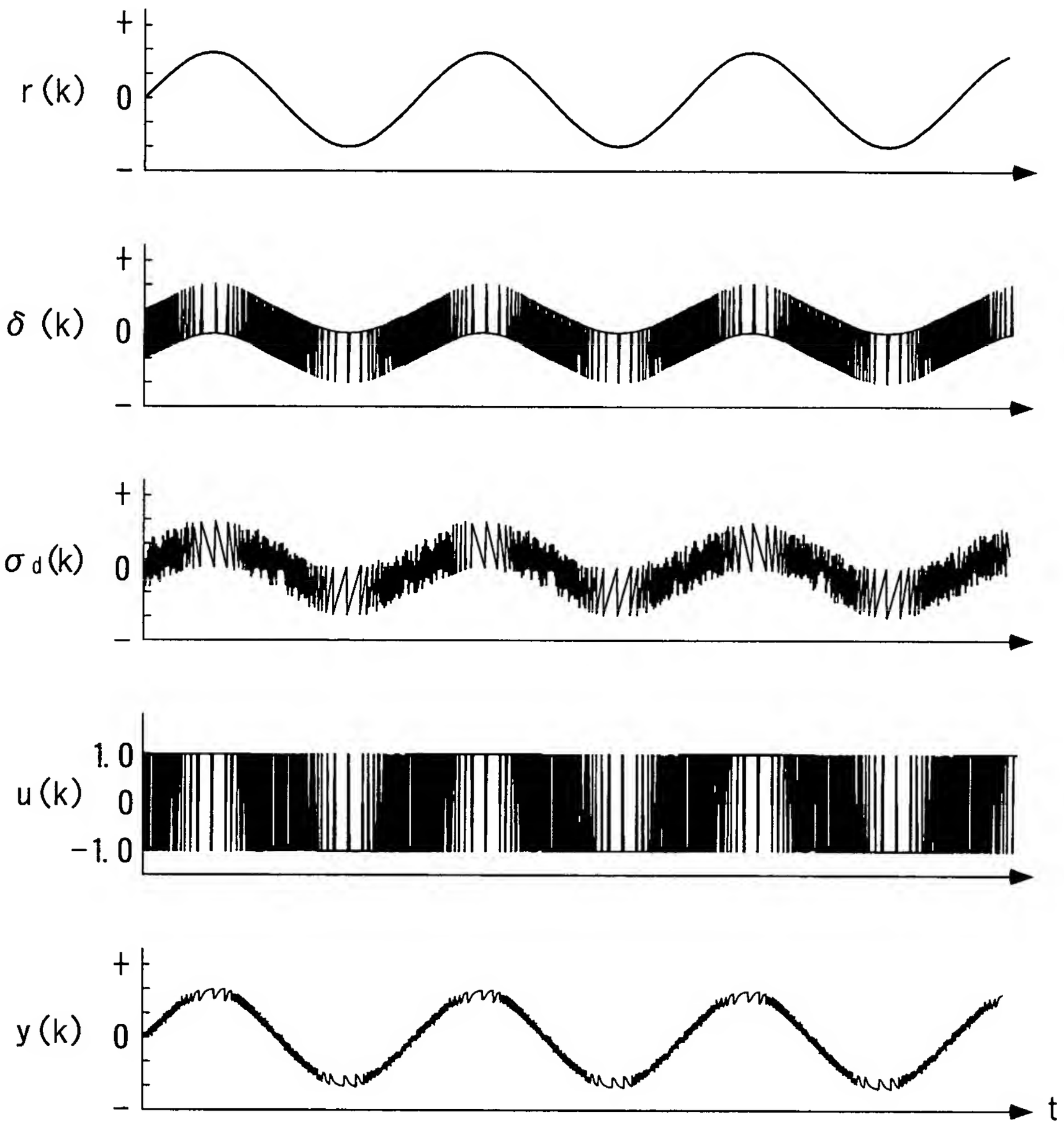


FIG. 8

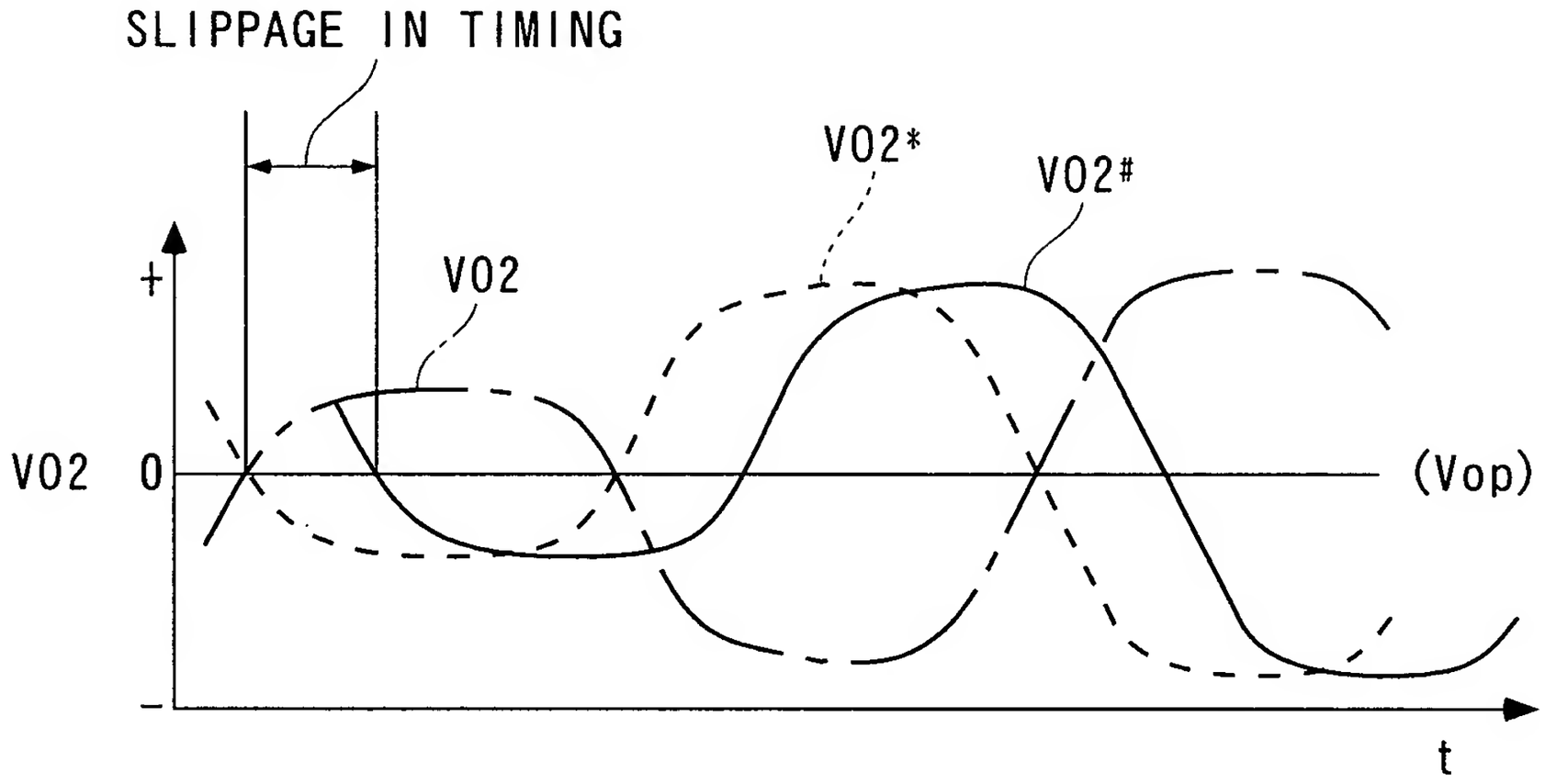


FIG. 9

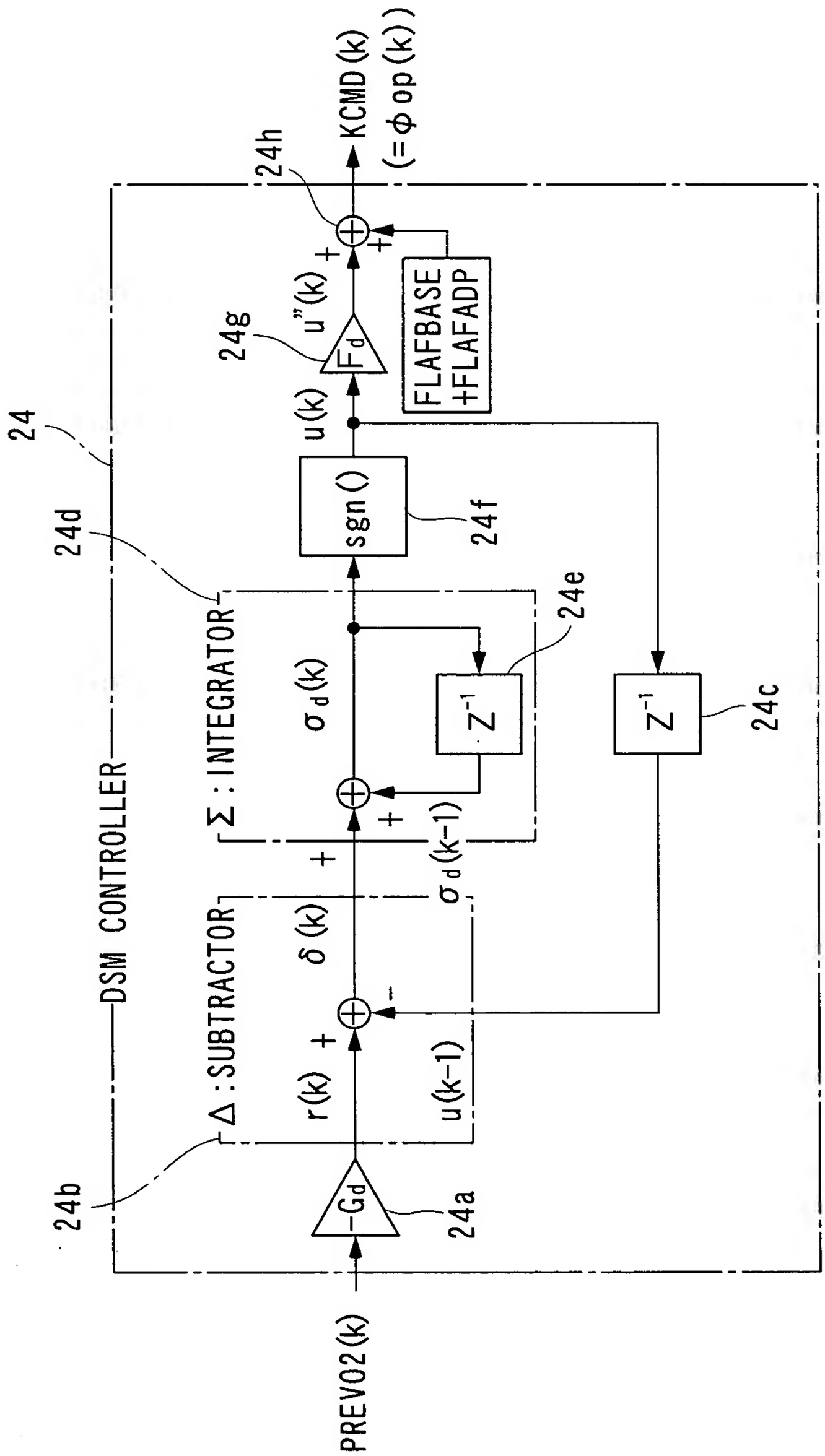

DSM CONTROLLER
24
24b
Δ:SUBTRACTOR
r(k)
δ(k)
u(k-1)
24a
−Gd
PREV02(k)
24d
Σ:INTEGRATOR
σd(k)
σd(k-1)
24e
Z-1
24c
24f
sgn()
u(k)
24g
Fd
u"(k)
FLAFBASE
+FLAFADP
KCMD(k)
(=φop(k))

FIG. 10

$$Usl(k)=Ueq(k)+Urch(k)+Uadp(k) \quad \cdots\cdots (26)$$

$$Ueq(k)=\frac{-1}{S1\cdot b1}\{[S1\cdot(a1-1)+S2]\cdot VO2(k+dt) + (S1\cdot a2-S2)\cdot VO2(k+dt-1)\} \quad \cdots\cdots (27)$$

$$Urch(k)=\frac{-F}{S1\cdot b1}\cdot\sigma(k+dt) \quad \cdots\cdots (28)$$

$$Uadp(k)=\frac{-G}{S1\cdot b1}\sum_{i=0}^{k+dt}\Delta T\cdot\sigma(i) \quad \cdots\cdots (29)$$

FIG. 11

$$\sigma PRE(k)=S1\cdot PREVO2(k)+S2\cdot PREVO2(k-1) \quad \cdots\cdots (30)$$

$$Usl(k)=Ueq(k)+Urch(k)+Uadp(k) \quad \cdots\cdots (31)$$

$$Ueq(k)=\frac{-1}{S1\cdot b1}\{[S1\cdot(a1-1)+S2]\cdot PREVO2(k) + (S1\cdot a2-S2)\cdot PREVO2(k-1)\} \quad \cdots\cdots (32)$$

$$Urch(k)=\frac{-F}{S1\cdot b1}\cdot\sigma PRE(k) \quad \cdots\cdots (33)$$

$$Uadp(k)=\frac{-G}{S1\cdot b1}\sum_{i=0}^{k}\Delta T\cdot\sigma PRE(i) \quad \cdots\cdots (34)$$

FIG. 12

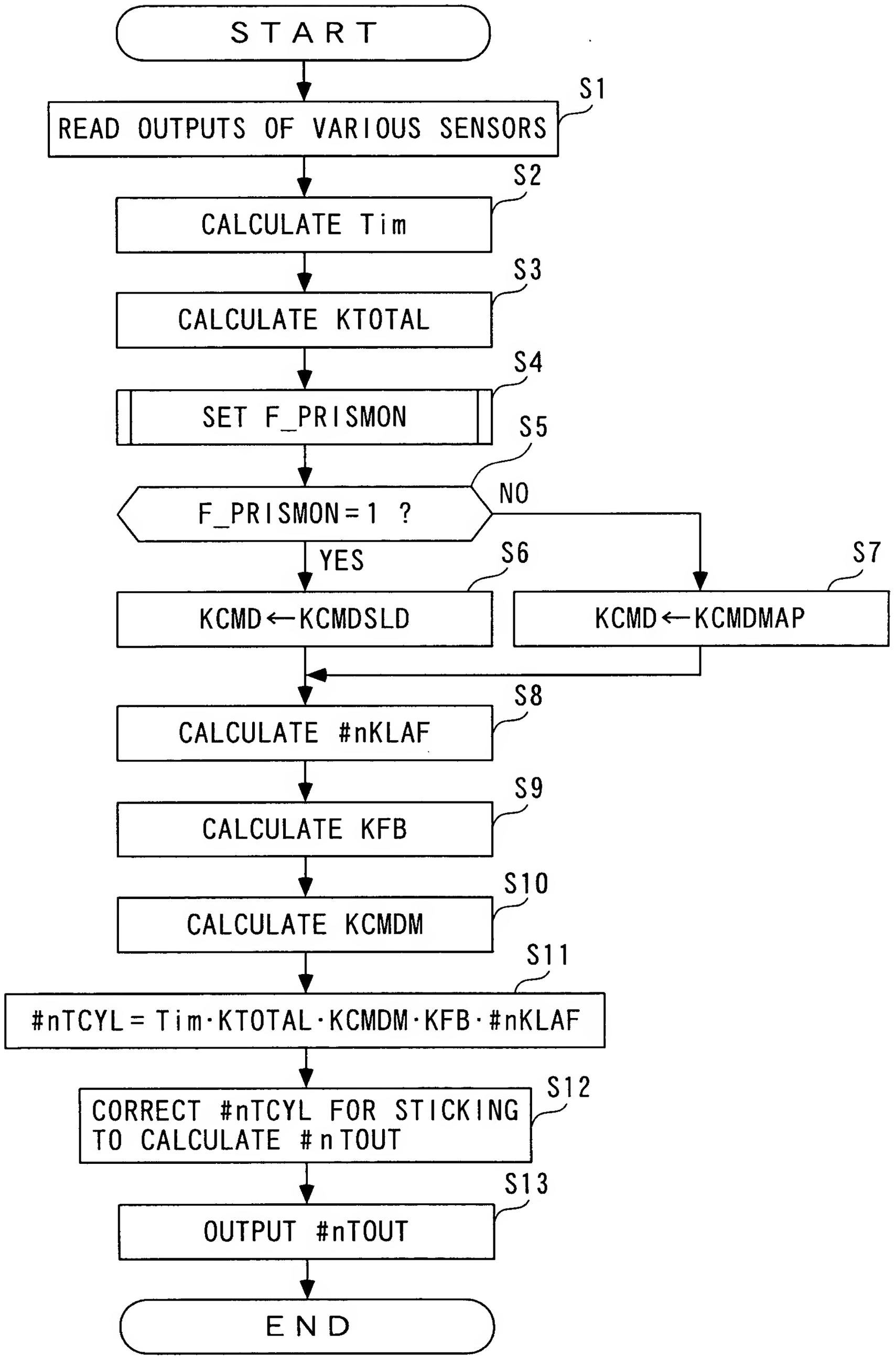

START
READ OUTPUTS OF VARIOUS SENSORS
S1
CALCULATE Tim
S2
CALCULATE KTOTAL
S3
SET F_PRISMON
S4
F_PRISMON=1 ?
S5
NO
YES
KCMD←KCMDSLD
S6
KCMD←KCMDMAP
S7
CALCULATE #nKLAF
S8
CALCULATE KFB
S9
CALCULATE KCMDM
S10
#nTCYL=Tim·KTOTAL·KCMDM·KFB·#nKLAF
S11
CORRECT #nTCYL FOR STICKING TO CALCULATE #nTOUT
S12
OUTPUT #nTOUT
S13
END

FIG. 13

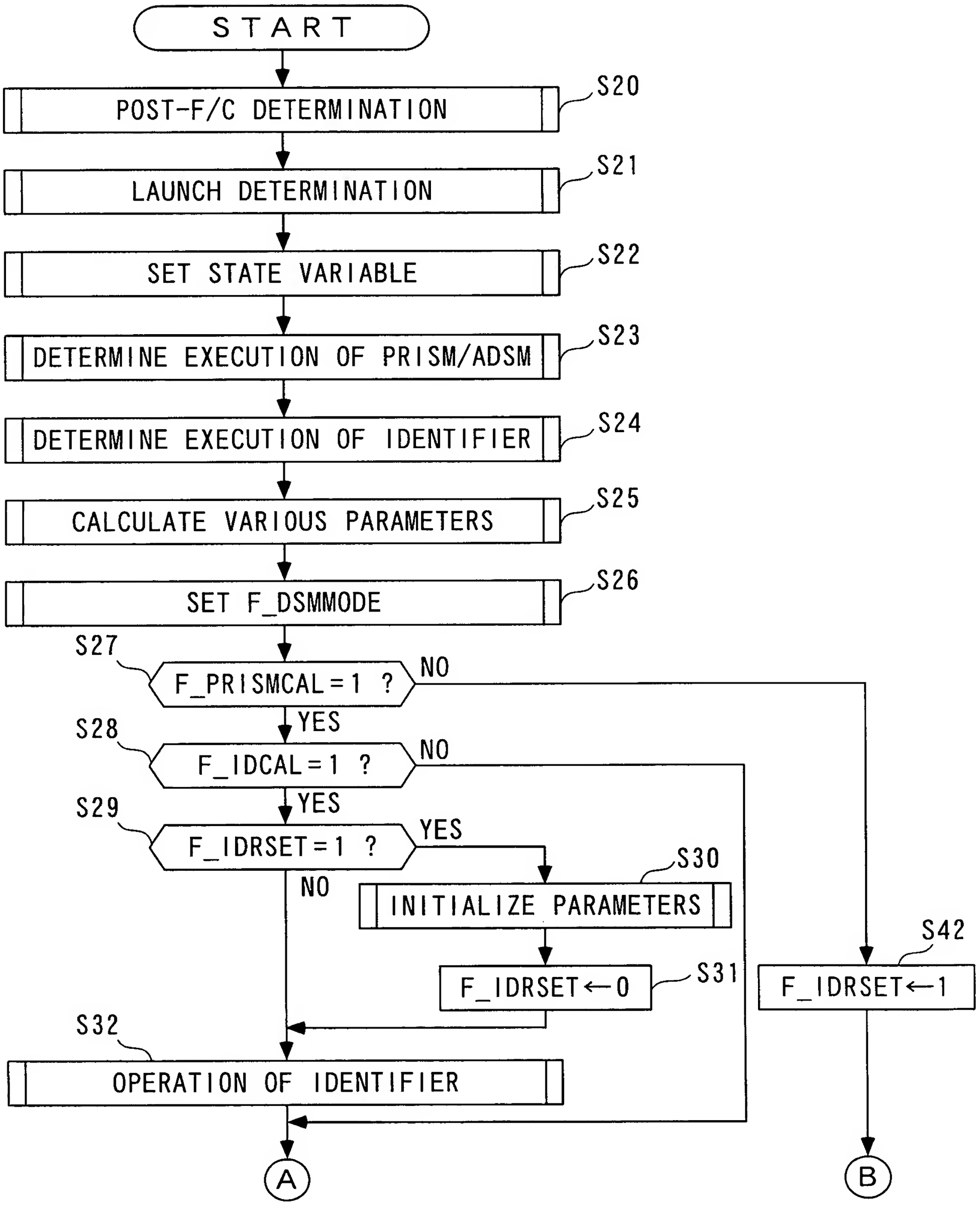

START
POST-F/C DETERMINATION
S20
LAUNCH DETERMINATION
S21
SET STATE VARIABLE
S22
DETERMINE EXECUTION OF PRISM/ADSM
S23
DETERMINE EXECUTION OF IDENTIFIER
S24
CALCULATE VARIOUS PARAMETERS
S25
SET F_DSMMODE
S26
S27
F_PRISMCAL=1 ?
NO
YES
S28
F_IDCAL=1 ?
NO
YES
S29
F_IDRSET=1 ?
YES
NO
S30
INITIALIZE PARAMETERS
F_IDRSET←0
S31
S32
OPERATION OF IDENTIFIER
A
S42
F_IDRSET←1
B

FIG. 14

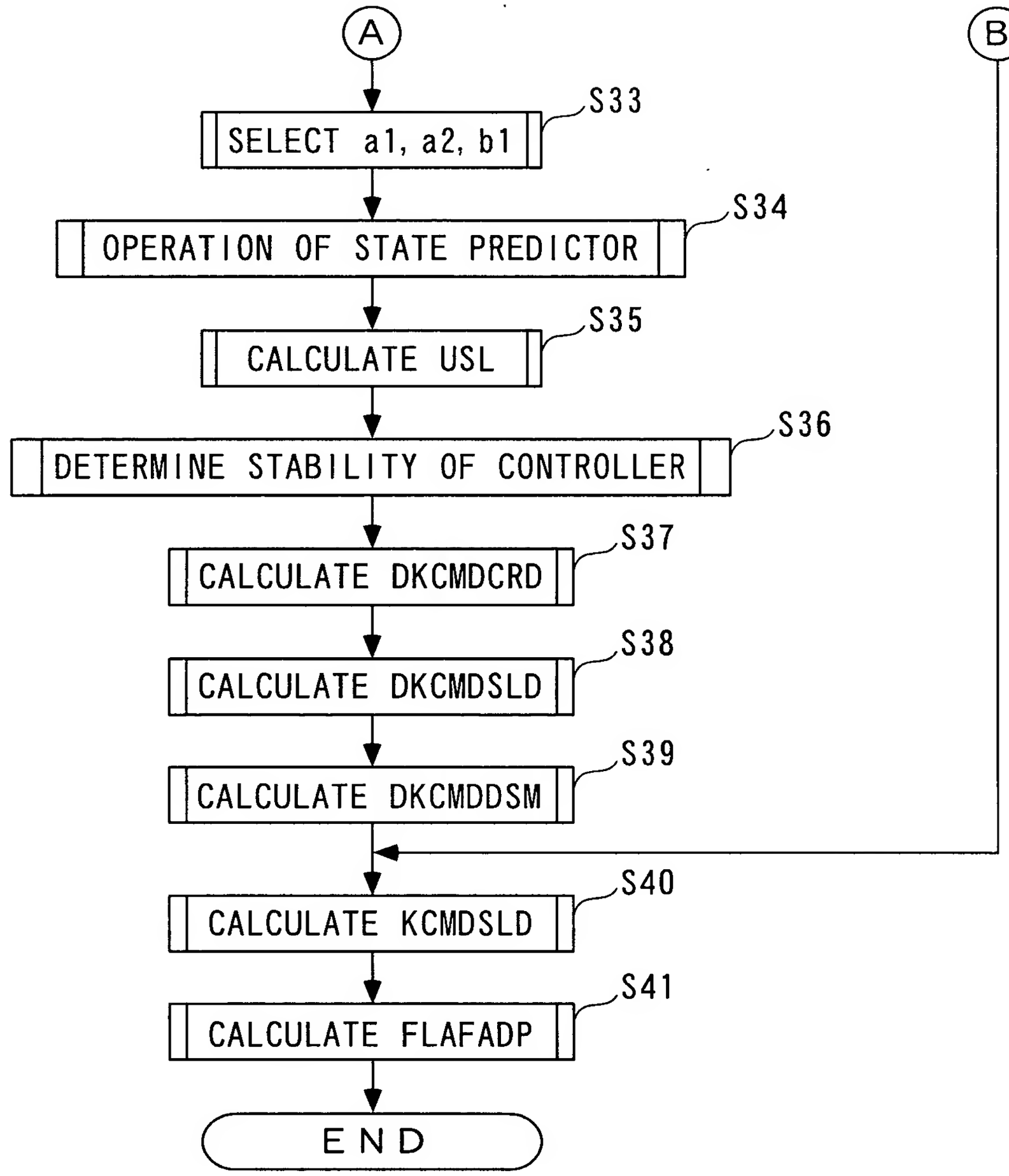

A
B
SELECT a1, a2, b1
S33
OPERATION OF STATE PREDICTOR
S34
CALCULATE USL
S35
DETERMINE STABILITY OF CONTROLLER
S36
CALCULATE DKCMDCRD
S37
CALCULATE DKCMDSLD
S38
CALCULATE DKCMDDSM
S39
CALCULATE KCMDSLD
S40
CALCULATE FLAFADP
S41
END

FIG. 15

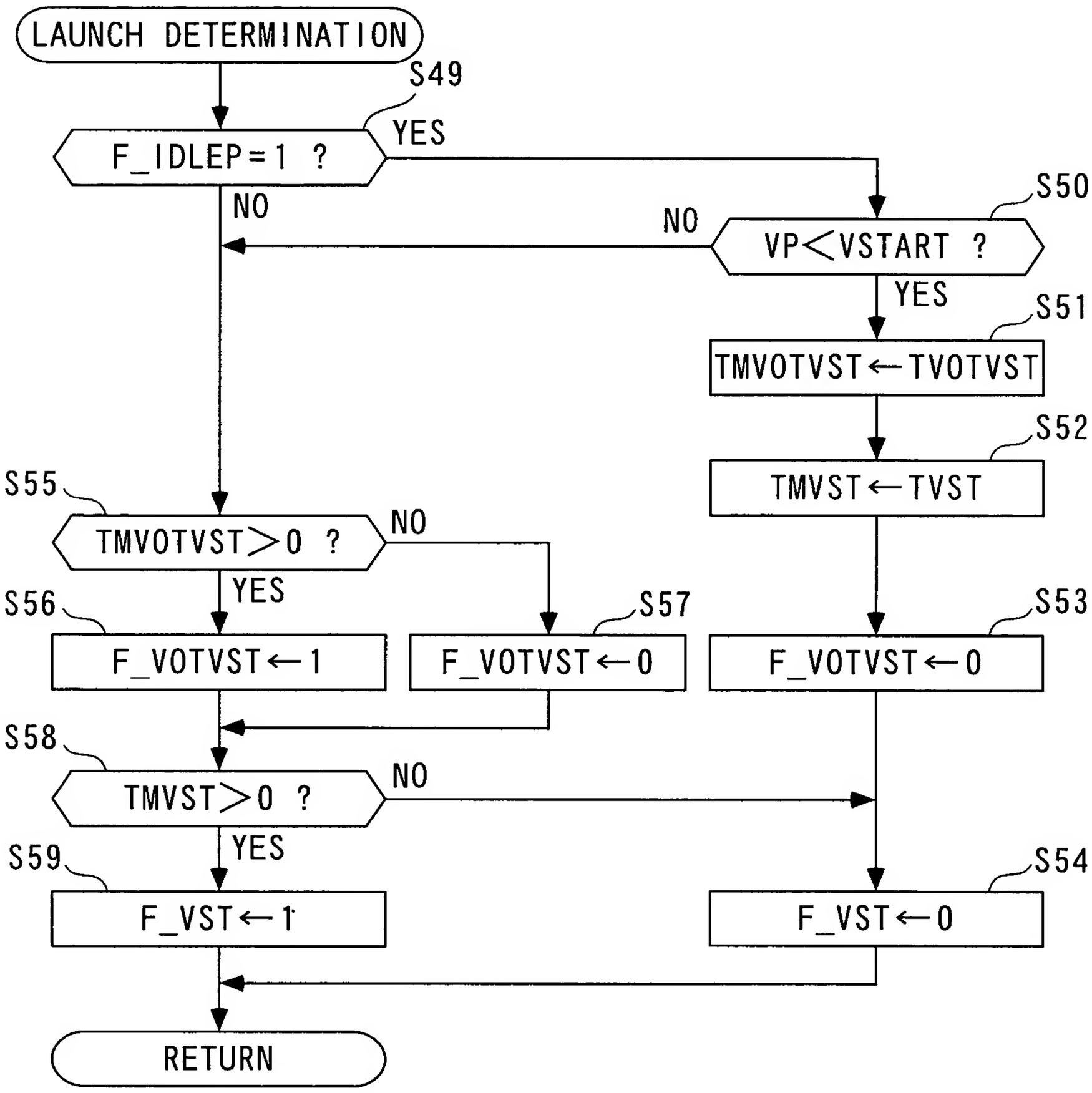

LAUNCH DETERMINATION
S49
F_IDLEP=1 ?
YES
NO
S50
VP<VSTART ?
NO
YES
S51
TMVOTVST←TVOTVST
S52
TMVST←TVST
S55
TMVOTVST>0 ?
NO
YES
S56
F_VOTVST←1
S57
F_VOTVST←0
S53
F_VOTVST←0
S58
TMVST>0 ?
NO
YES
S59
F_VST←1
S54
F_VST←0
RETURN

FIG. 16

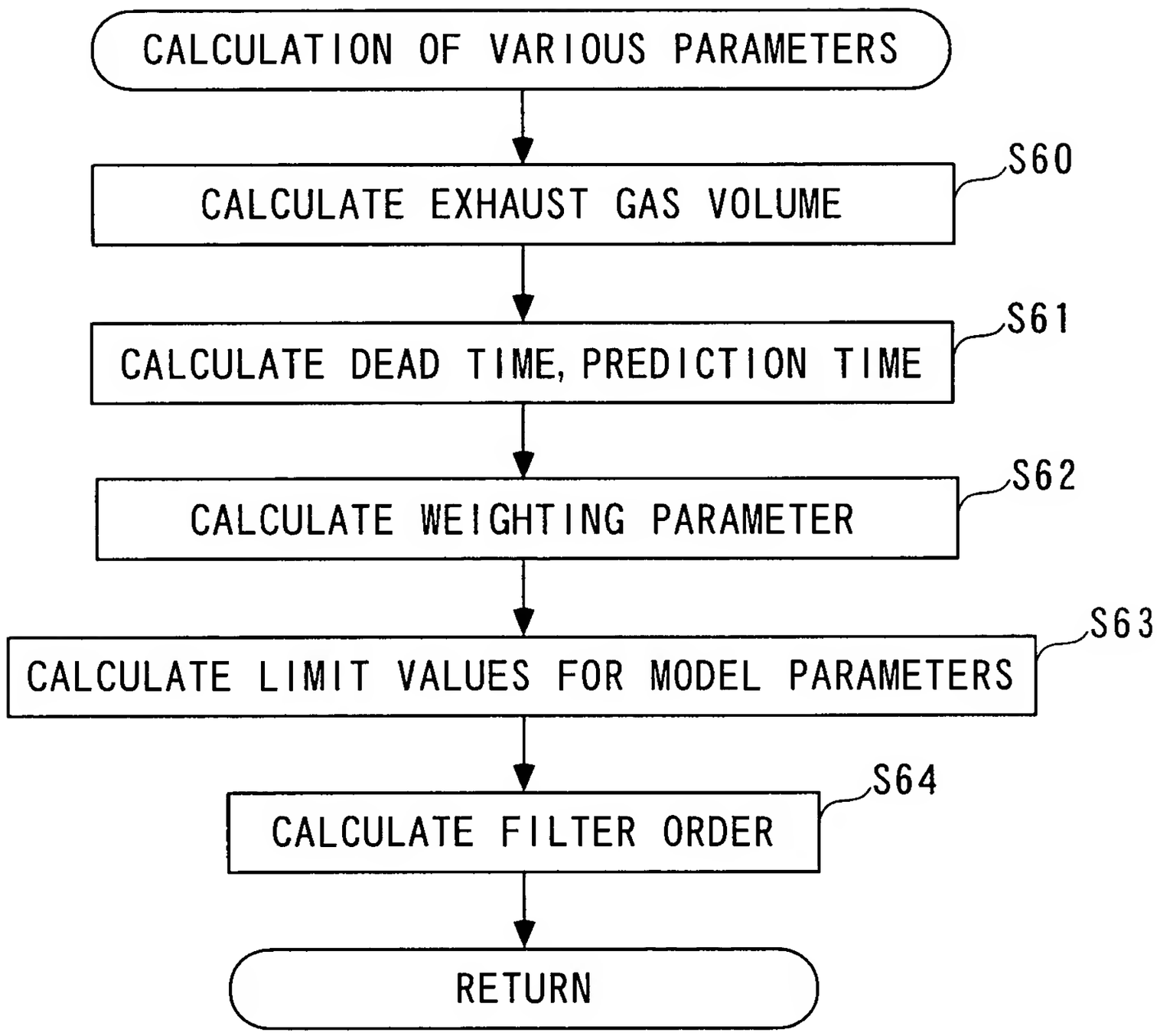

CALCULATION OF VARIOUS PARAMETERS
CALCULATE EXHAUST GAS VOLUME
S60
CALCULATE DEAD TIME, PREDICTION TIME
S61
CALCULATE WEIGHTING PARAMETER
S62
CALCULATE LIMIT VALUES FOR MODEL PARAMETERS
S63
CALCULATE FILTER ORDER
S64
RETURN

FIG. 17

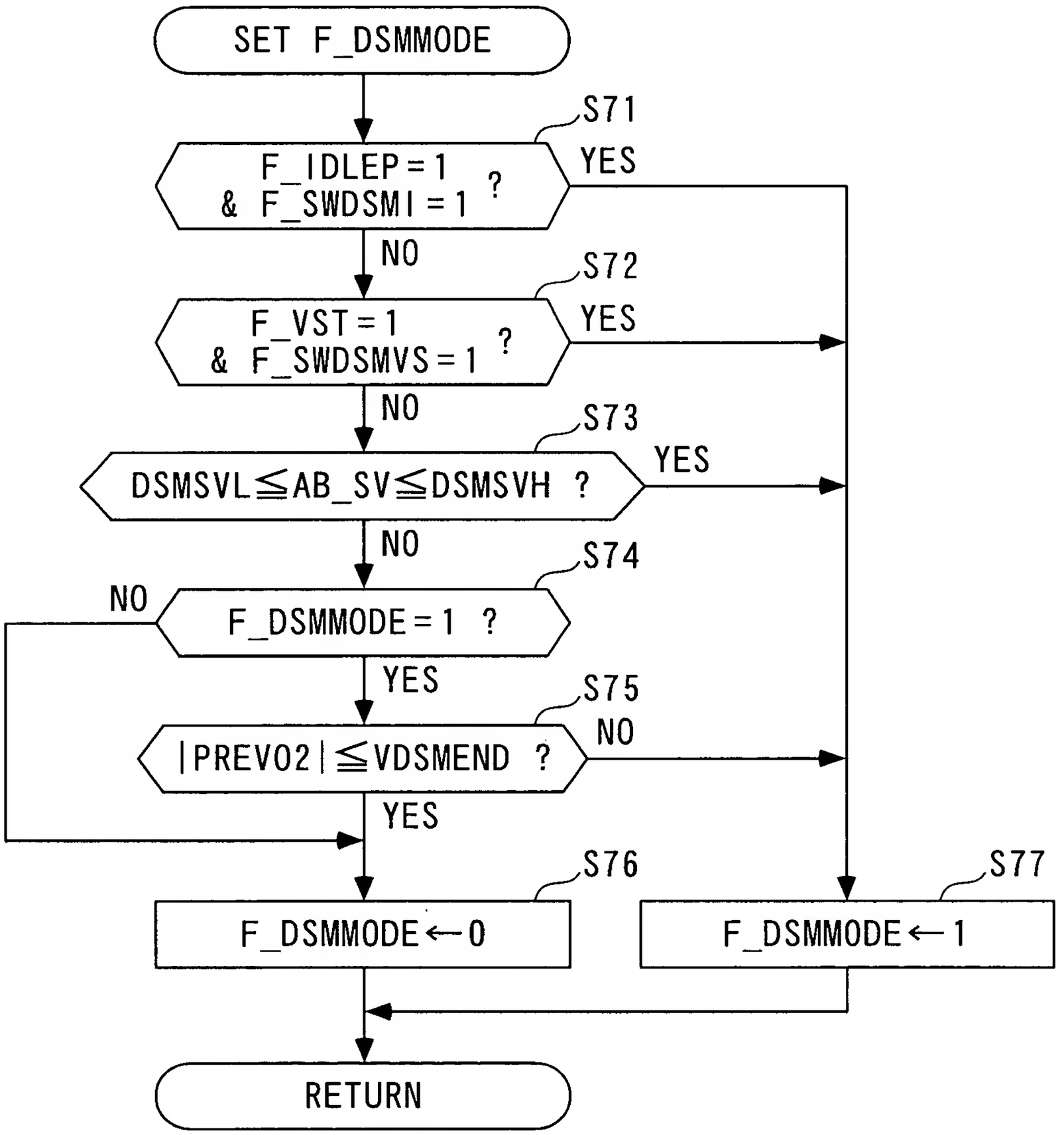

SET F_DSMMODE
S71
F_IDLEP=1 & F_SWDSMI=1 ?
YES
NO
S72
F_VST=1 & F_SWDSMVS=1 ?
YES
NO
S73
DSMSVL≦AB_SV≦DSMSVH ?
YES
NO
S74
NO
F_DSMMODE=1 ?
YES
S75
|PREV02|≦VDSMEND ?
NO
YES
S76
F_DSMMODE←0
S77
F_DSMMODE←1
RETURN

FIG. 18

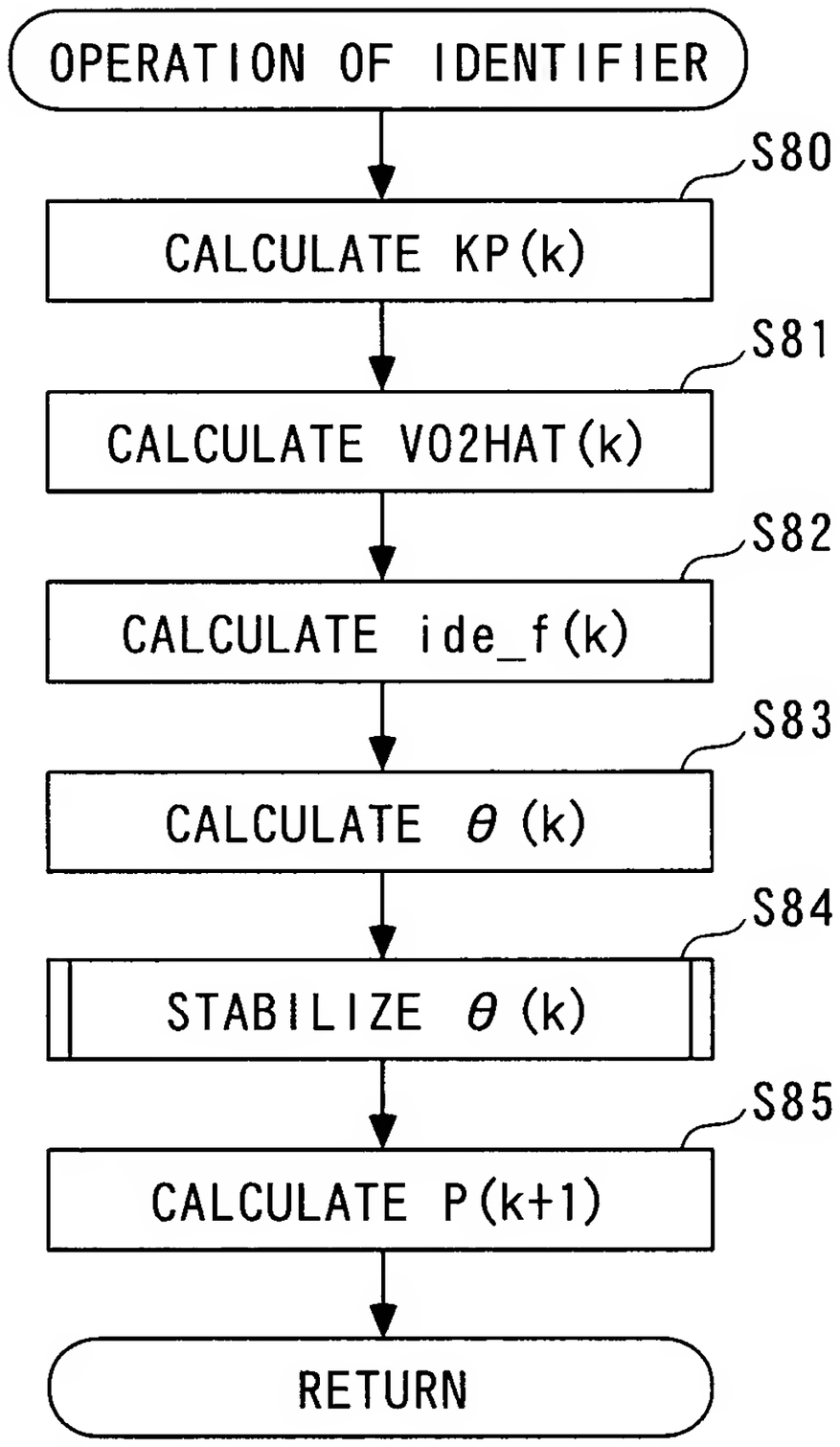

OPERATION OF IDENTIFIER
S80
CALCULATE KP(k)
S81
CALCULATE VO2HAT(k)
S82
CALCULATE ide_f(k)
S83
CALCULATE θ(k)
S84
STABILIZE θ(k)
S85
CALCULATE P(k+1)
RETURN

FIG. 19

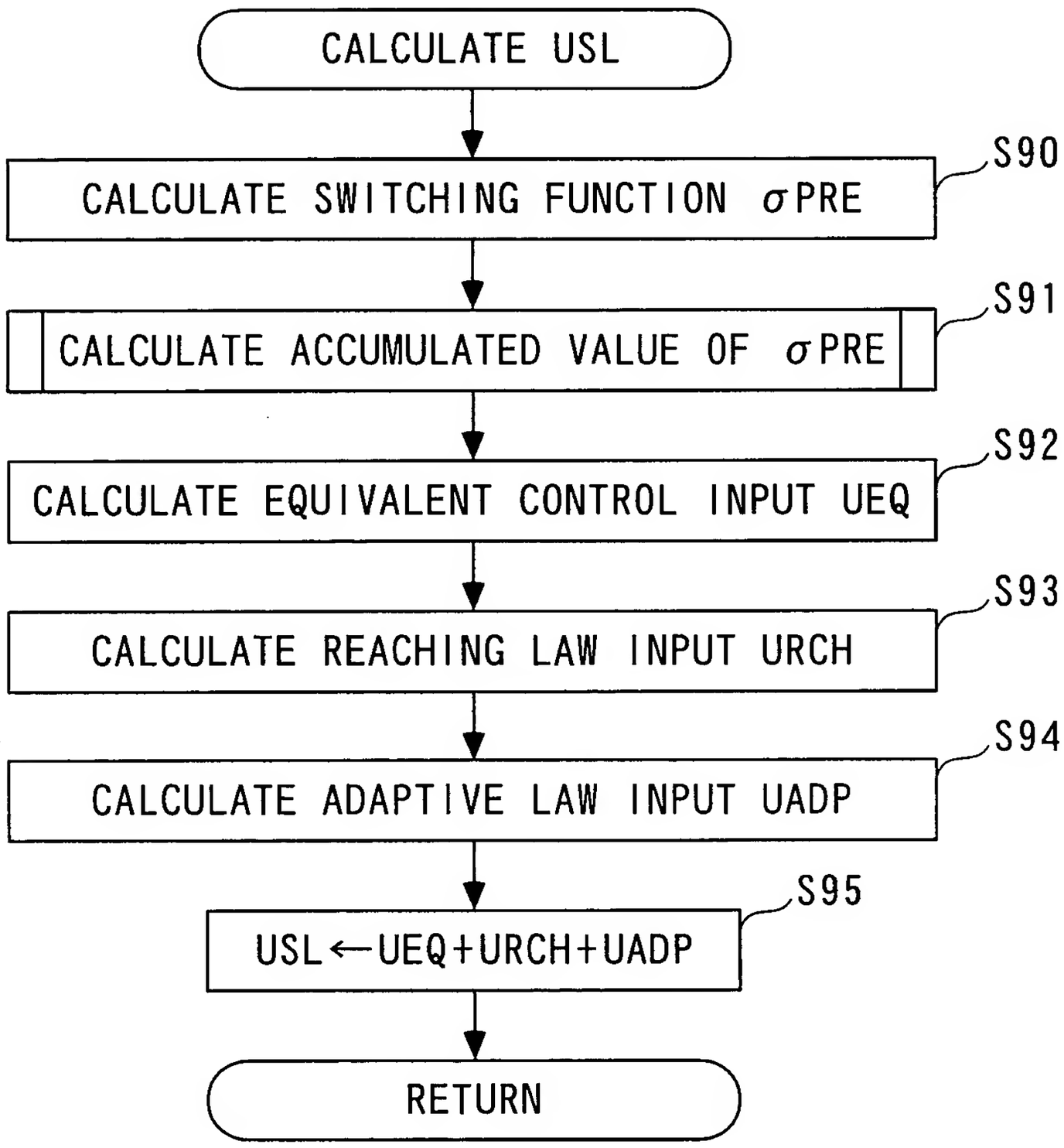

CALCULATE USL
CALCULATE SWITCHING FUNCTION σPRE
S90
CALCULATE ACCUMULATED VALUE OF σPRE
S91
CALCULATE EQUIVALENT CONTROL INPUT UEQ
S92
CALCULATE REACHING LAW INPUT URCH
S93
CALCULATE ADAPTIVE LAW INPUT UADP
S94
USL←UEQ+URCH+UADP
S95
RETURN

FIG. 20

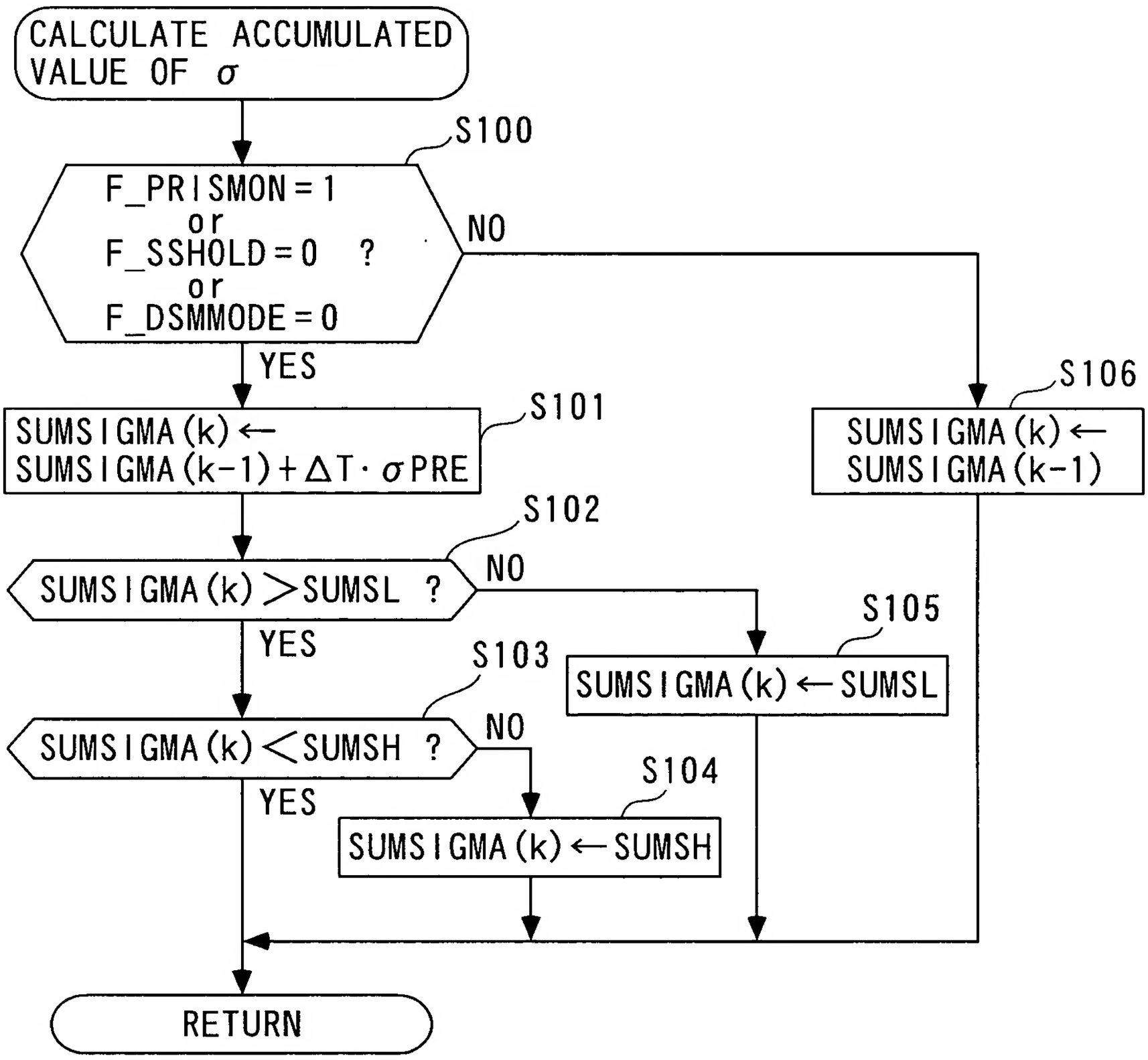

CALCULATE ACCUMULATED VALUE OF σ
S100
F_PRISMON = 1 or F_SSHOLD = 0 ? or F_DSMMODE = 0
NO
YES
S101
SUMSIGMA(k) ← SUMSIGMA(k-1) + ΔT · σPRE
S102
SUMSIGMA(k) > SUMSL ?
NO
YES
S103
SUMSIGMA(k) < SUMSH ?
NO
YES
S104
SUMSIGMA(k) ← SUMSH
S105
SUMSIGMA(k) ← SUMSL
S106
SUMSIGMA(k) ← SUMSIGMA(k-1)
RETURN

FIG. 21

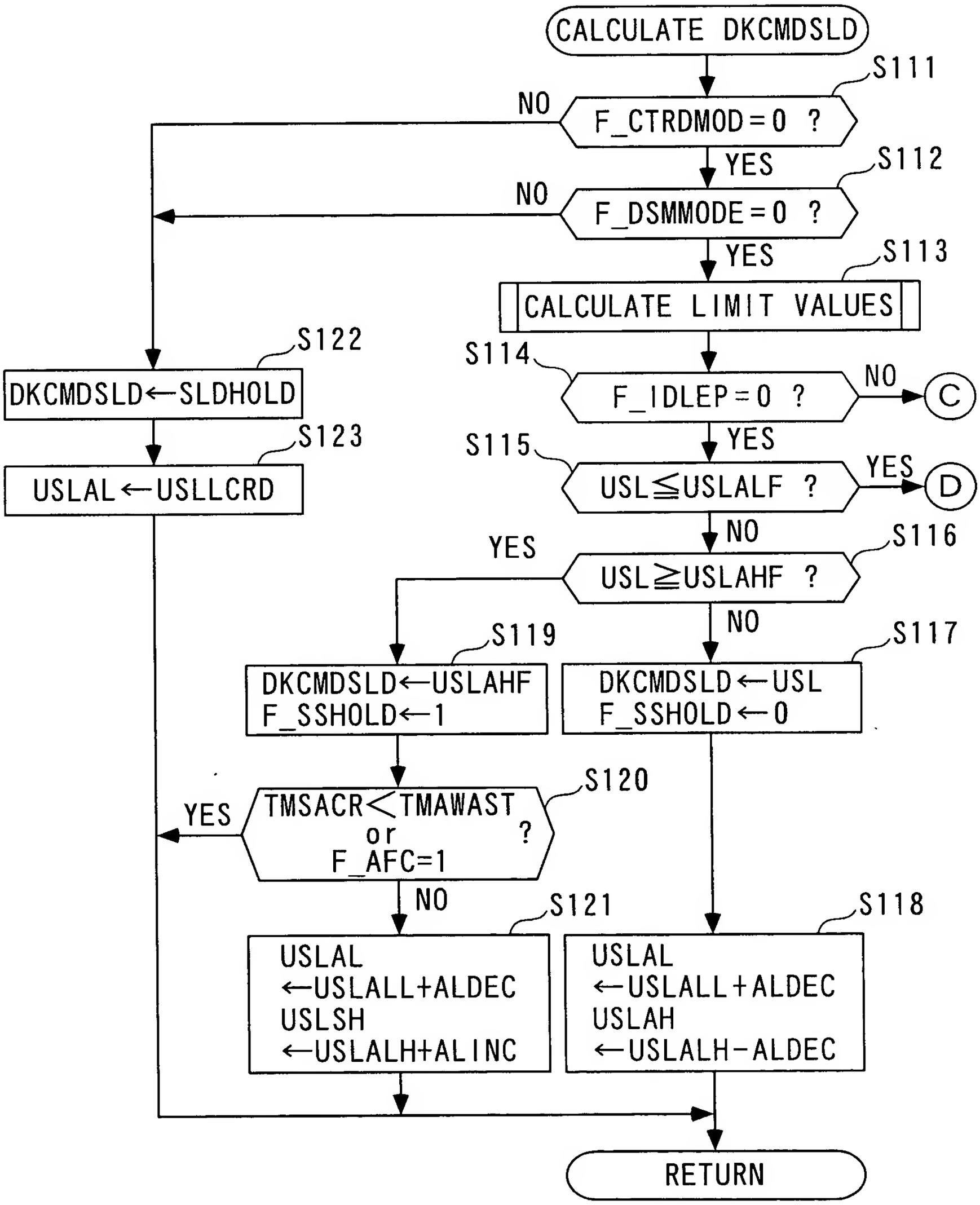

CALCULATE DKCMDSLD
S111
F_CTRDMOD=0 ?
NO
YES
S112
F_DSMMODE=0 ?
NO
YES
S113
CALCULATE LIMIT VALUES
S114
F_IDLEP=0 ?
NO
C
YES
S115
USL≦USLALF ?
YES
D
NO
S116
USL≧USLAHF ?
YES
NO
S122
DKCMDSLD←SLDHOLD
S123
USLAL←USLLCRD
S119
DKCMDSLD←USLAHF
F_SSHOLD←1
S117
DKCMDSLD←USL
F_SSHOLD←0
S120
TMSACR<TMAWAST
or
F_AFC=1
?
YES
NO
S121
USLAL
←USLALL+ALDEC
USLSH
←USLALH+ALINC
S118
USLAL
←USLALL+ALDEC
USLAH
←USLALH-ALDEC
RETURN

FIG. 22

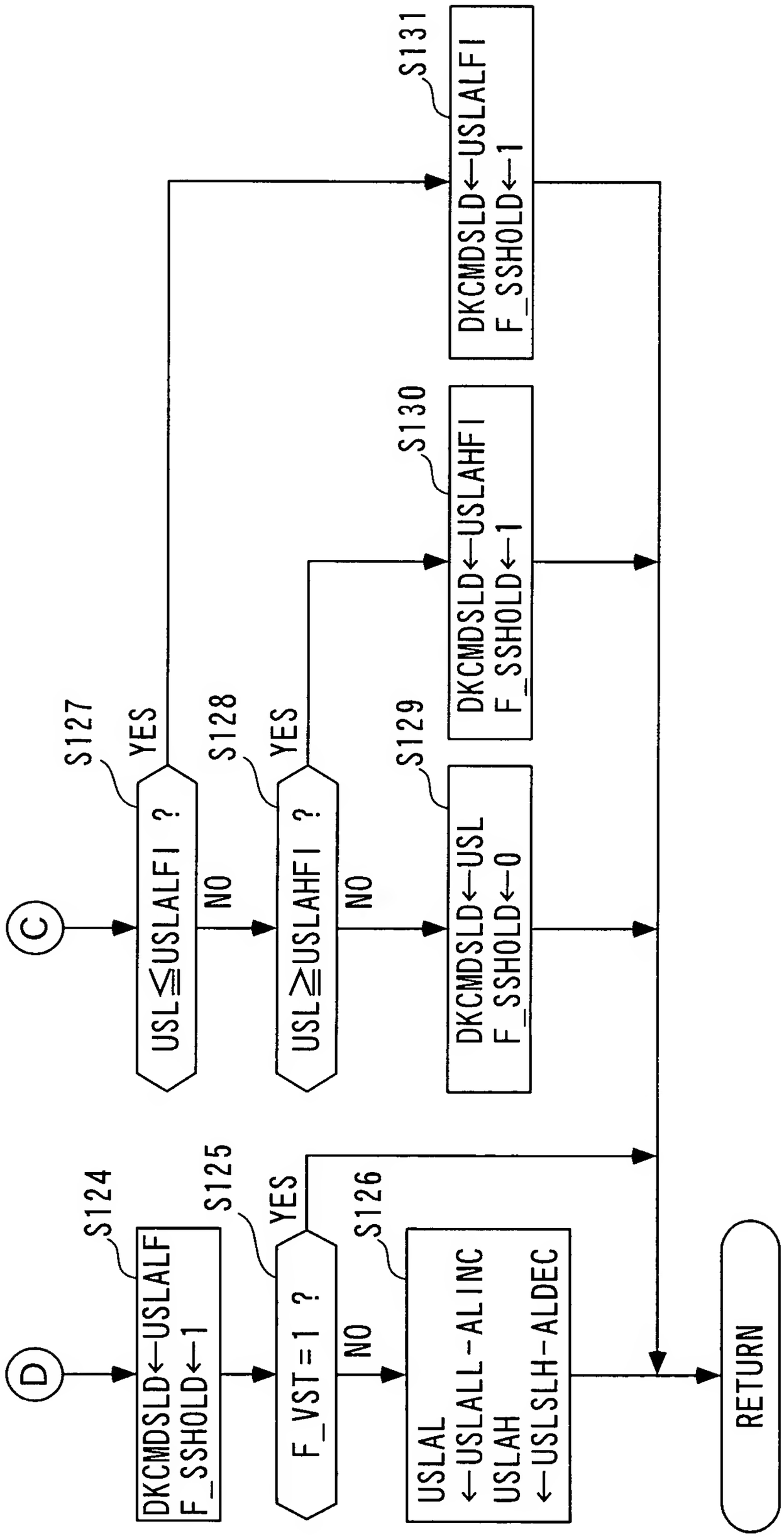

S131
DKCMDSLD←USLALFI
F_SSHOLD←1
S130
DKCMDSLD←USLAHFI
F_SSHOLD←1
S129
DKCMDSLD←USL
F_SSHOLD←0
S127
USL≦USLALFI ?
YES
NO
S128
USL≧USLAHFI ?
YES
NO
C
S124
DKCMDSLD←USLALF
F_SSHOLD←1
S125
F_VST=1 ?
YES
NO
S126
USLAL
←USLALL-ALINC
USLAH
←USLSLH-ALDEC
D
RETURN

FIG. 23

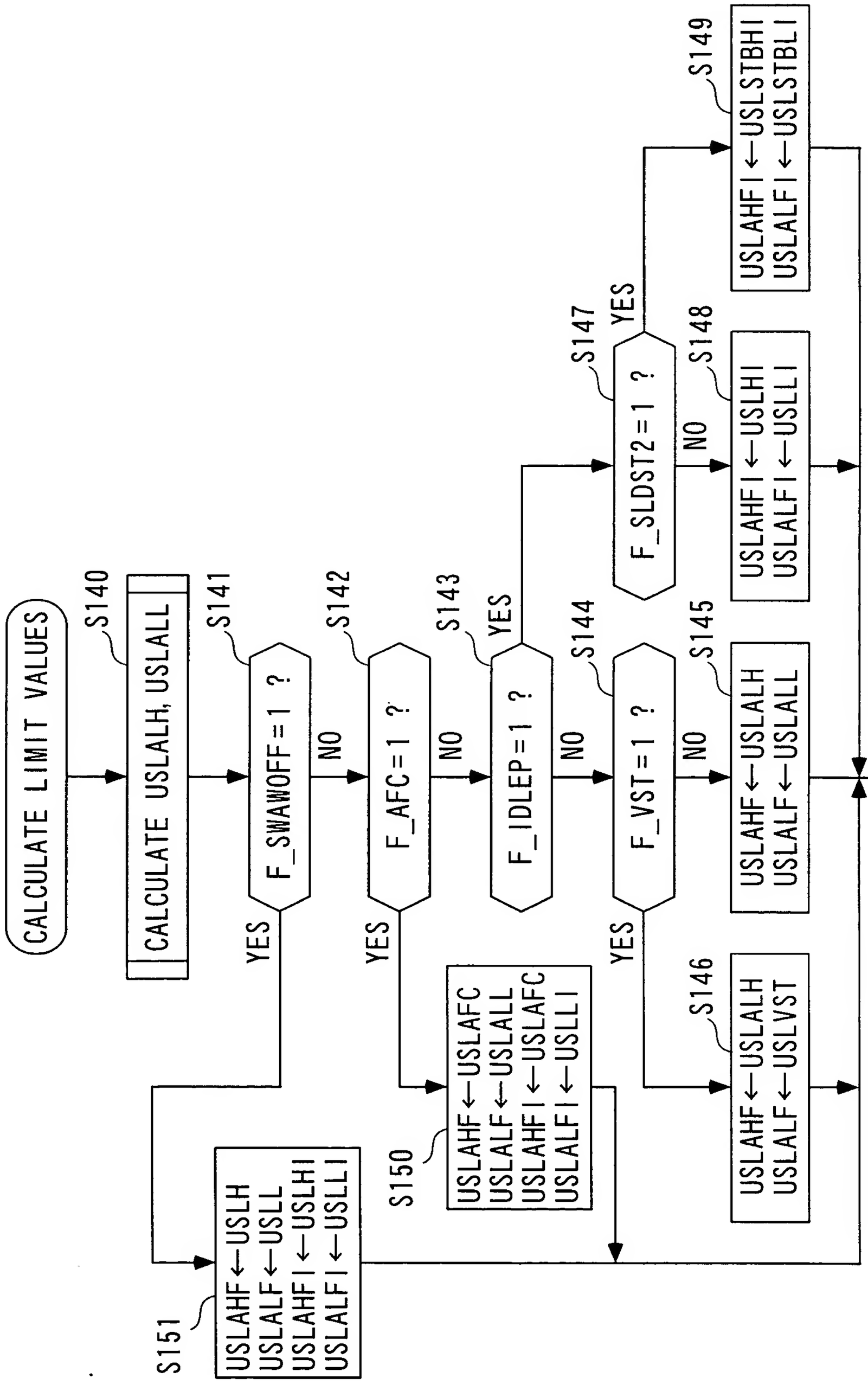

CALCULATE LIMIT VALUES
S140
CALCULATE USLAH, USLALL
S141
F_SWAWOFF=1 ?
YES
NO
S142
F_AFC=1 ?
YES
NO
S143
F_IDLEP=1 ?
YES
NO
S144
F_VST=1 ?
YES
NO
S145
USLAHF←USLAH
USLALF←USLALL
S146
USLAHF←USLAH
USLALF←USLVST
S147
F_SLDST2=1 ?
YES
NO
S148
USLAHF←USLHI
USLALF←USLLI
S149
USLAHF←USLHI
USLALF←USLLI
S150
USLAHF←USLAFC
USLALF←USLALL
USLAHF←USLAFC
USLALF←USLLI
S151
USLAHF←USLH
USLALF←USLL
USLAHF←USLHI
USLALF←USLLI
RETURN

FIG. 24

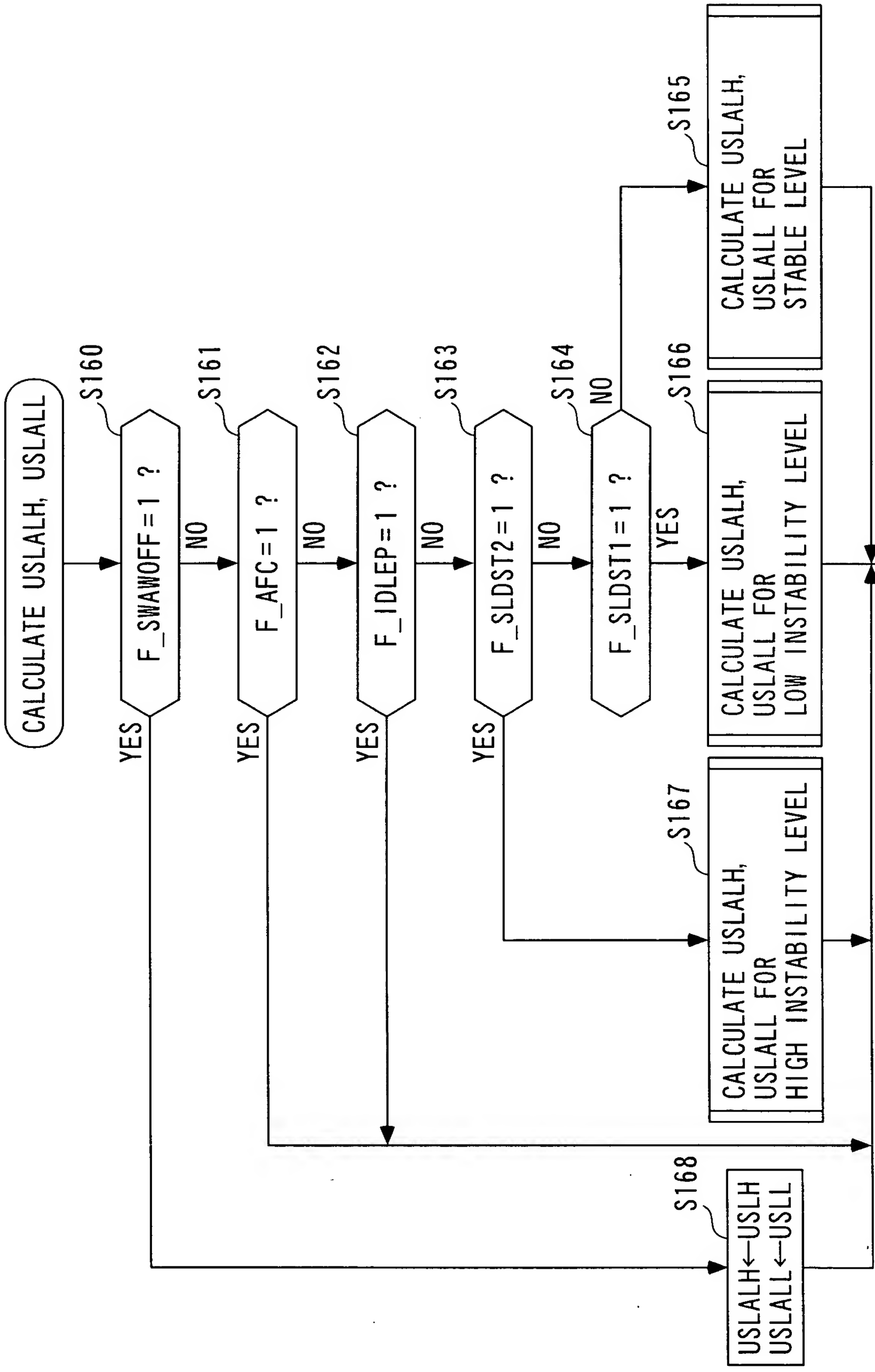

CALCULATE USLALH, USLALL
S160
F_SWAWOFF=1 ?
YES
NO
S161
F_AFC=1 ?
YES
NO
S162
F_IDLEP=1 ?
YES
NO
S163
F_SLDST2=1 ?
YES
NO
S164
F_SLDST1=1 ?
NO
YES
S165
CALCULATE USLALH, USLALL FOR STABLE LEVEL
S166
CALCULATE USLALH, USLALL FOR LOW INSTABILITY LEVEL
S167
CALCULATE USLALH, USLALL FOR HIGH INSTABILITY LEVEL
S168
USLALH←USLH
USLALL←USLL
RETURN

FIG. 25

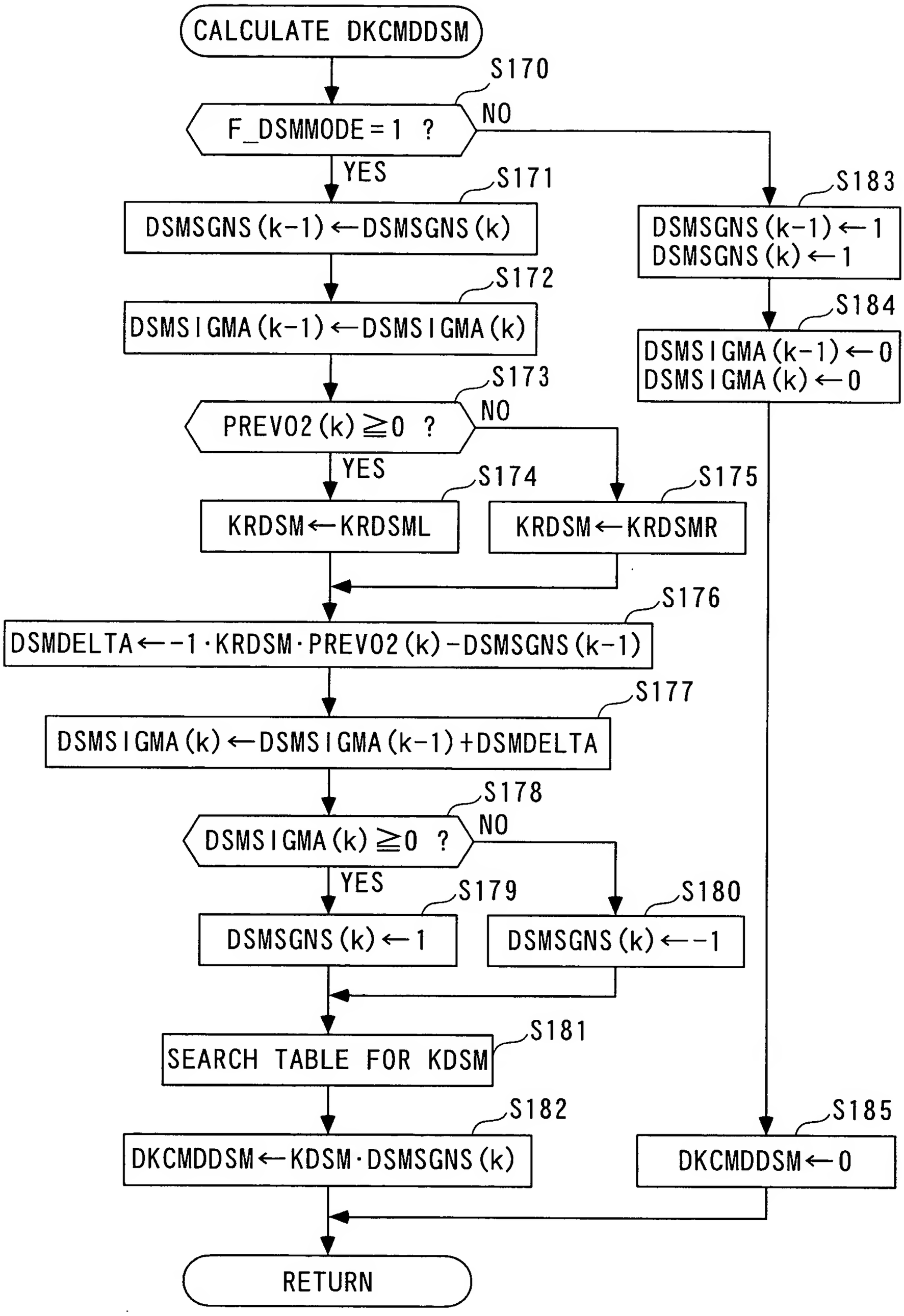

CALCULATE DKCMDDSM
S170
F_DSMMODE=1 ?
NO
YES
S171
DSMSGNS(k-1)←DSMSGNS(k)
S172
DSMSIGMA(k-1)←DSMSIGMA(k)
S173
PREVO2(k)≧0 ?
NO
YES
S174
KRDSM←KRDSML
S175
KRDSM←KRDSMR
S176
DSMDELTA←-1·KRDSM·PREVO2(k)-DSMSGNS(k-1)
S177
DSMSIGMA(k)←DSMSIGMA(k-1)+DSMDELTA
S178
DSMSIGMA(k)≧0 ?
NO
YES
S179
DSMSGNS(k)←1
S180
DSMSGNS(k)←-1
S181
SEARCH TABLE FOR KDSM
S182
DKCMDDSM←KDSM·DSMSGNS(k)
S183
DSMSGNS(k-1)←1
DSMSGNS(k)←1
S184
DSMSIGMA(k-1)←0
DSMSIGMA(k)←0
S185
DKCMDDSM←0
RETURN

FIG. 26

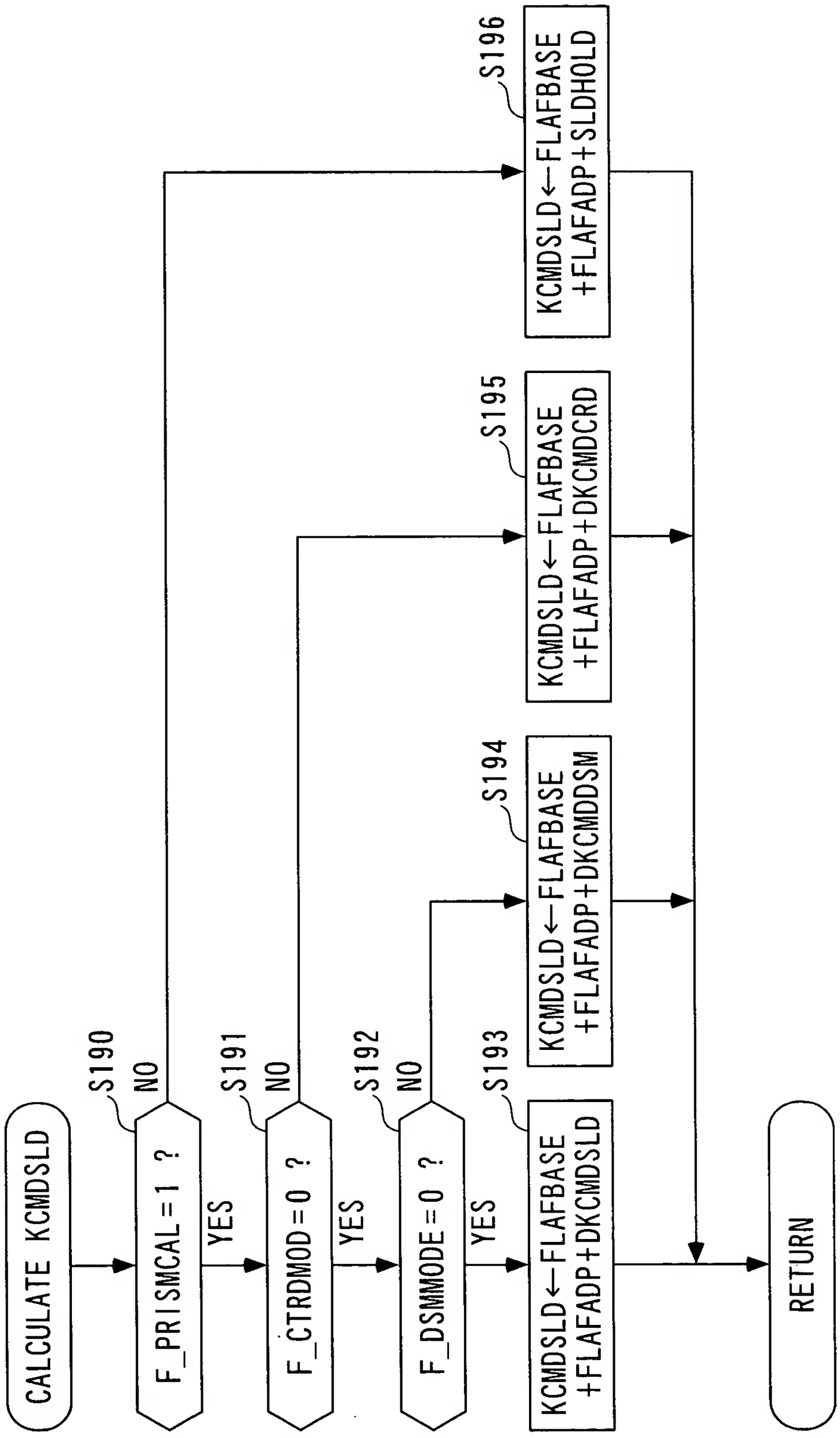

CALCULATE KCMDSLD
F_PRISMCAL=1 ?
YES
NO
S190
F_CTRDMOD=0 ?
YES
NO
S191
F_DSMMODE=0 ?
YES
NO
S192
KCMDSLD←FLAFBASE +FLAFADP+DKCMDSLD
S193
KCMDSLD←FLAFBASE +FLAFADP+DKCMDDSM
S194
KCMDSLD←FLAFBASE +FLAFADP+DKCMDCRD
S195
KCMDSLD←FLAFBASE +FLAFADP+SLDHOLD
S196
RETURN

FIG. 27

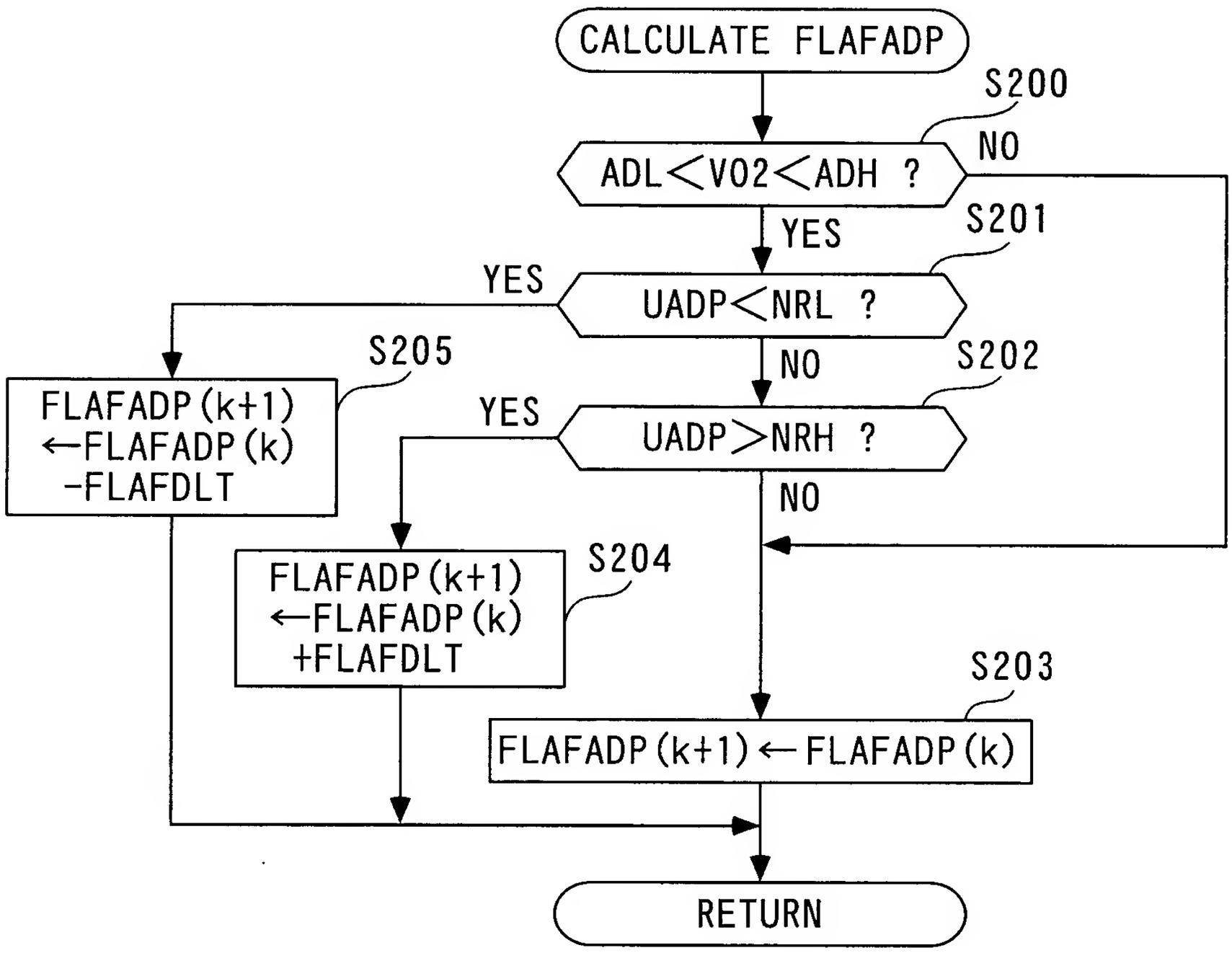

CALCULATE FLAFADP
S200
ADL<VO2<ADH ?
NO
YES
S201
UADP<NRL ?
YES
S205
FLAFADP(k+1)
←FLAFADP(k)
-FLAFDLT
NO
S202
UADP>NRH ?
YES
NO
S204
FLAFADP(k+1)
←FLAFADP(k)
+FLAFDLT
S203
FLAFADP(k+1)←FLAFADP(k)
RETURN

FIG. 28

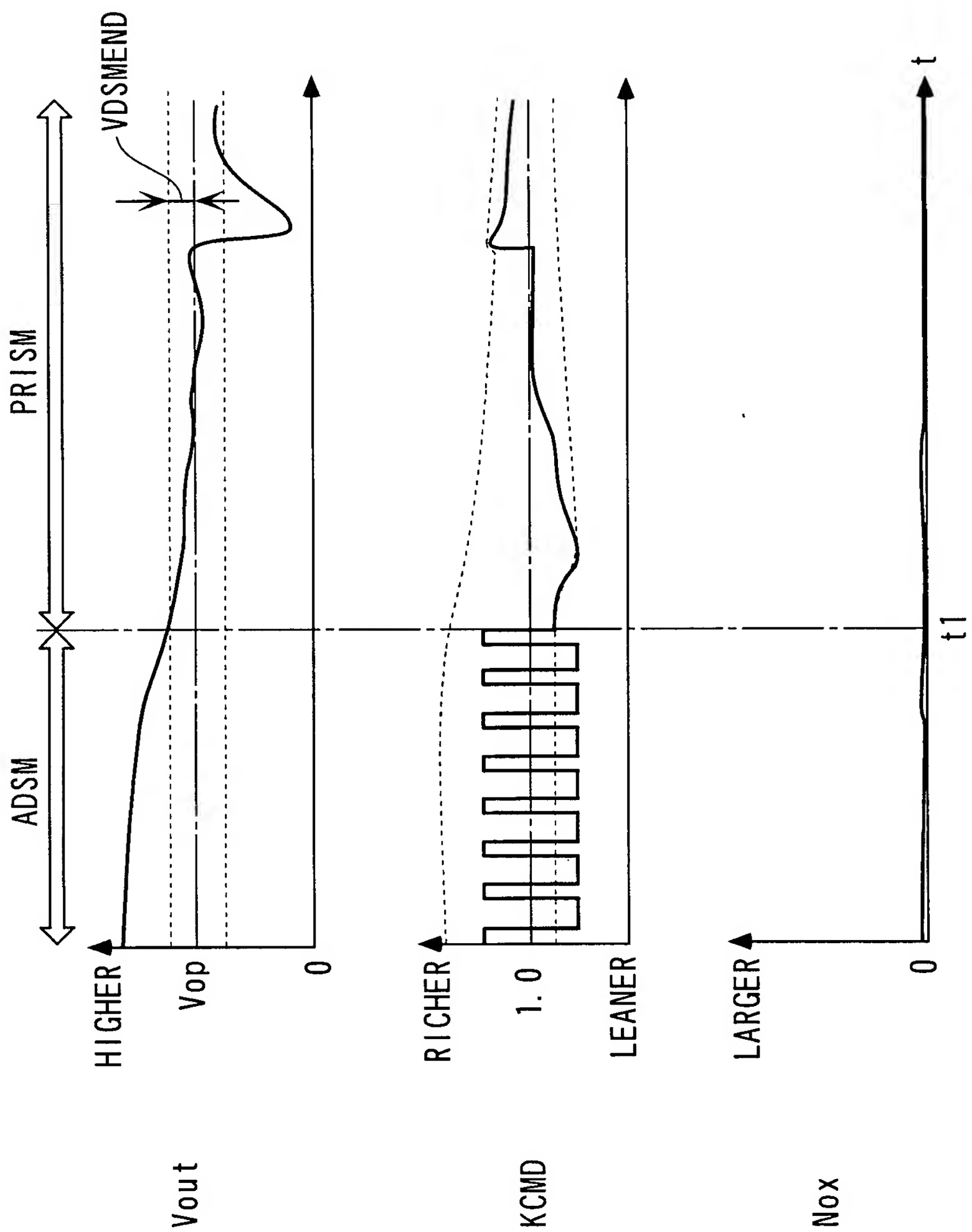

VDSMEND
PRISM
ADSM
t
t1
HIGHER
Vop
0
Vout
RICHER
1.0
KCMD
LEANER
LARGER
Nox
0

FIG. 29

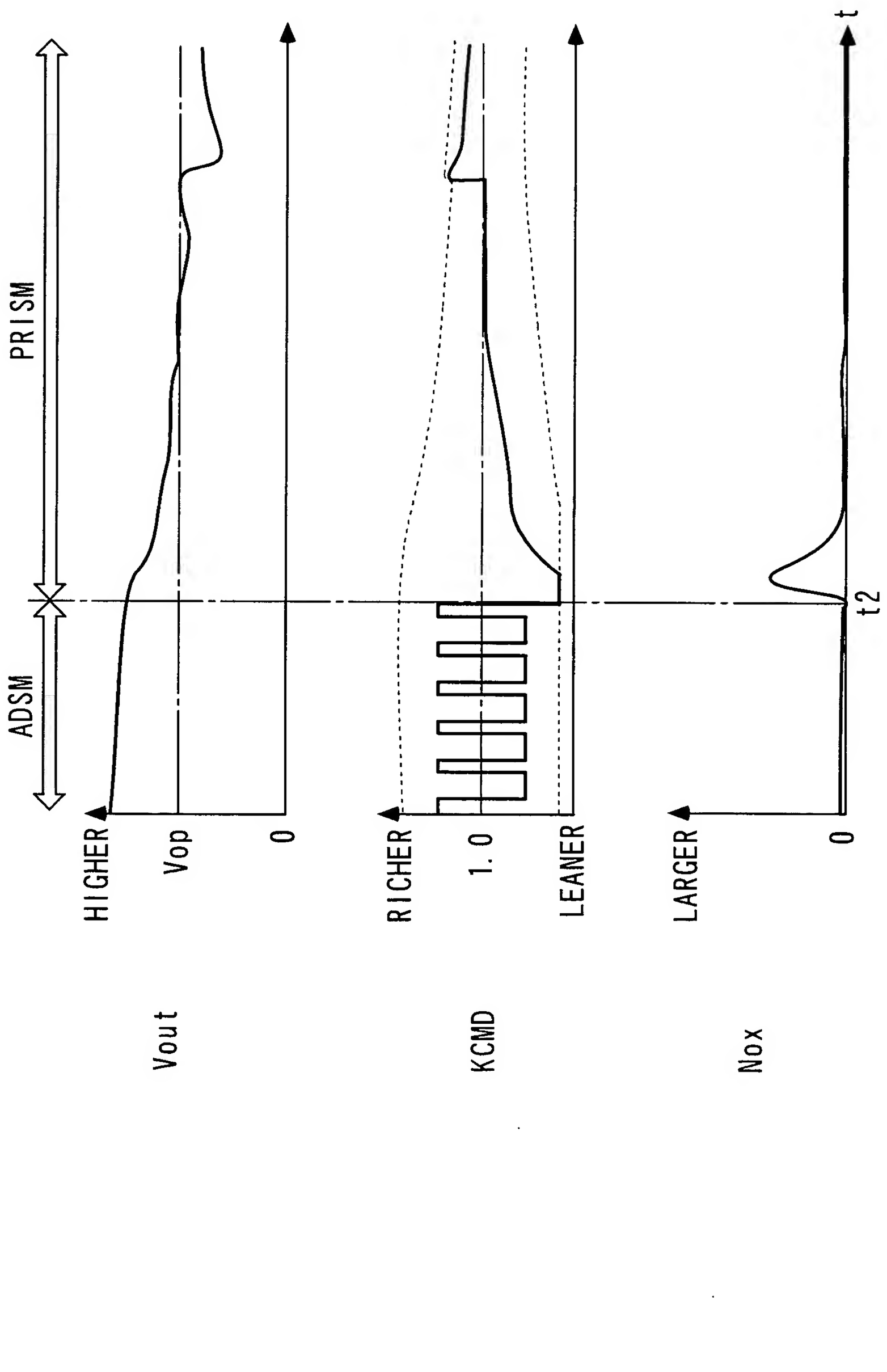

PRISM
ADSM
t2
HIGHER
Vop
0
Vout
RICHER
1.0
KCMD
LEANER
LARGER
0
Nox

FIG. 30

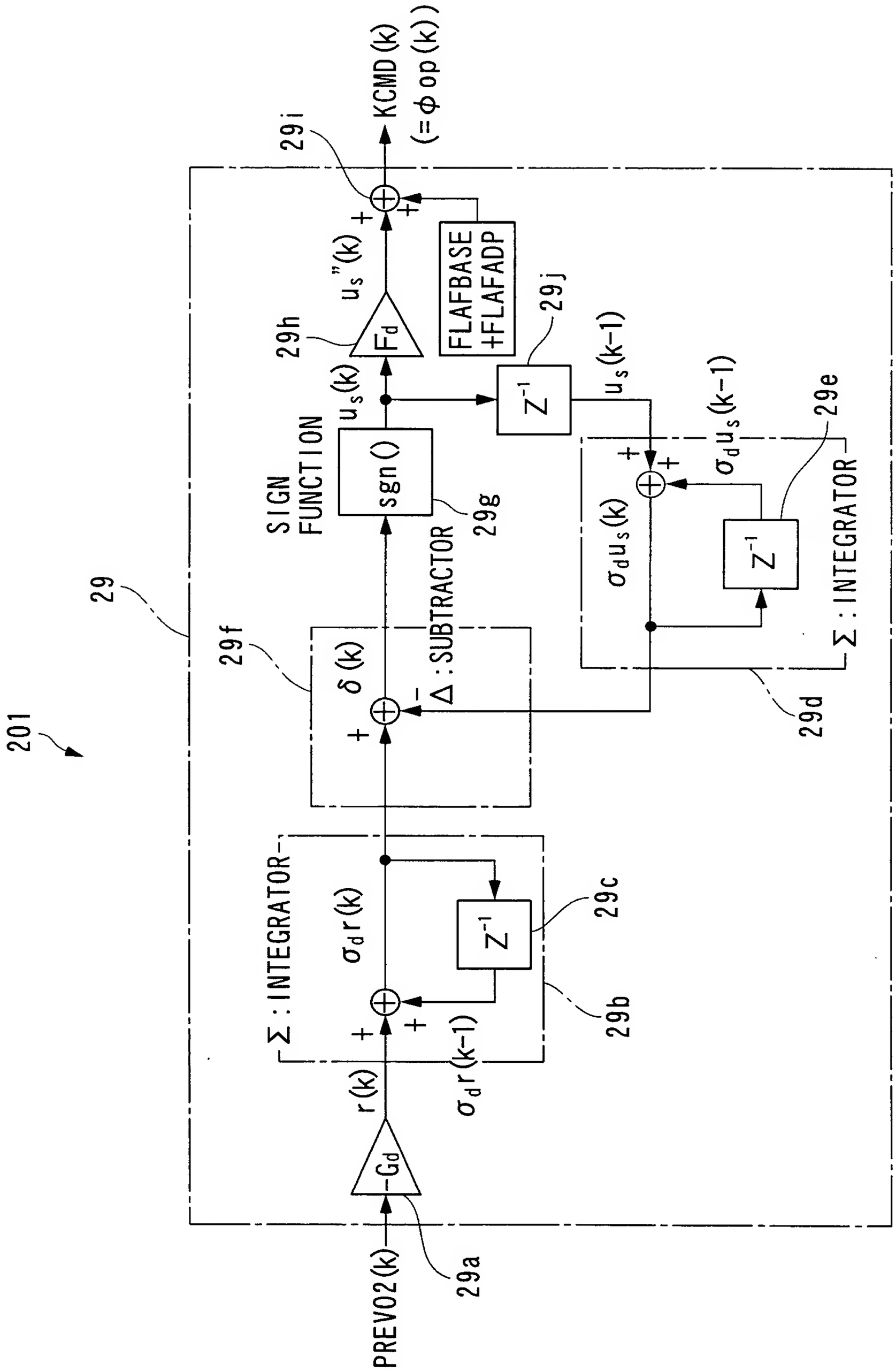
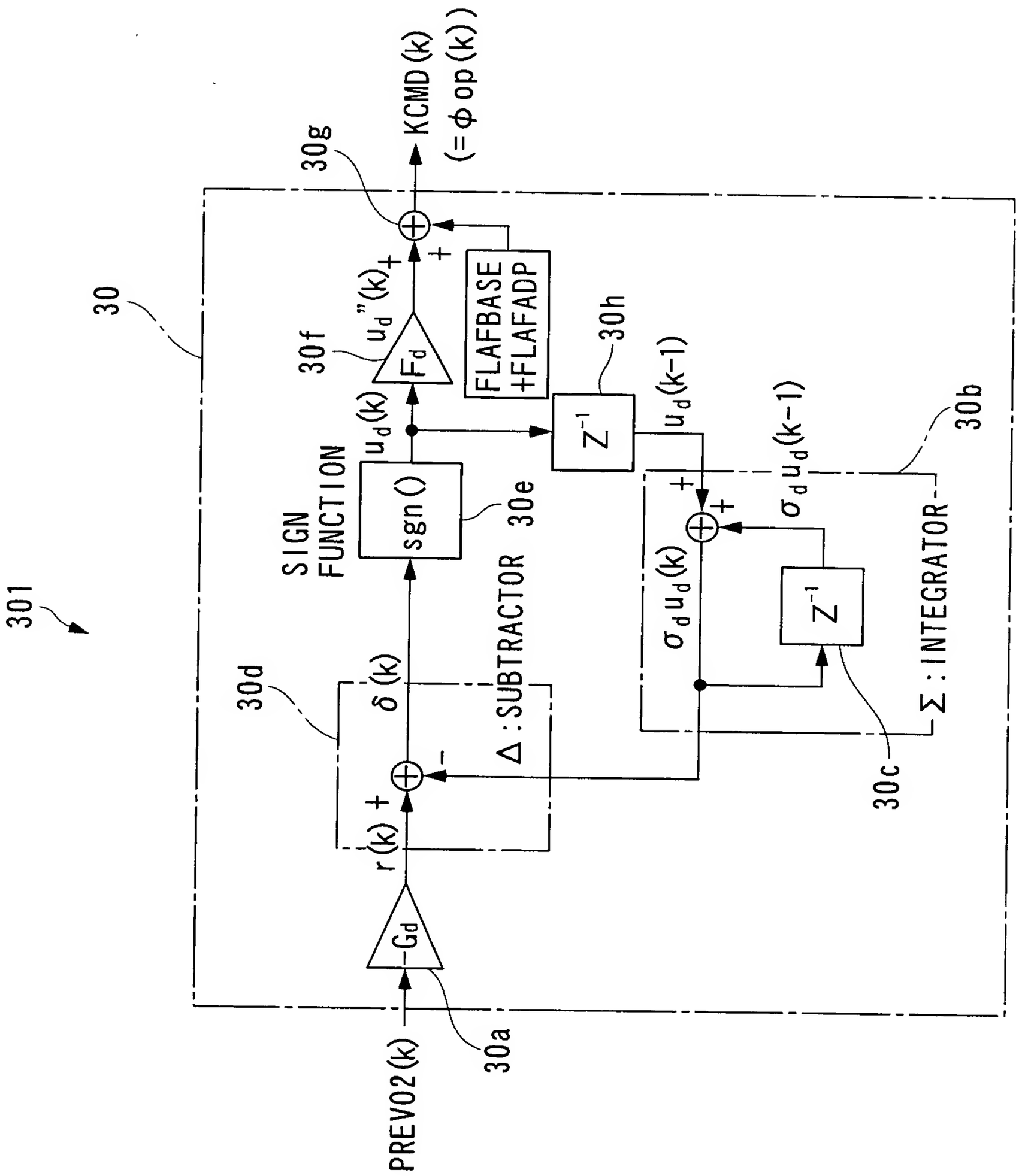

201
29
KCMD(k)
(=θop(k))
29i
+
+
FLAFBASE
+FLAFADP
29j
29h
Fd
us"(k)
+
+
Z-1
us(k-1)
us(k)
SIGN
FUNCTION
sgn()
29g
σdus(k-1)
29e
σdus(k)
+
+
Z-1
Σ:INTEGRATOR
29f
δ(k)
+
−
Δ:SUBTRACTOR
29d
Σ:INTEGRATOR
σdr(k)
Z-1
29c
+
+
29b
σdr(k-1)
r(k)
-Gd
PREVO2(k)
29a

FIG. 31


301
30
PREVO2(k)
30a
Gd
r(k)
30d
δ(k)
Δ:SUBTRACTOR
SIGN FUNCTION
sgn()
30e
ud(k)
Fd
30f
ud"(k)+
30g
KCMD(k)
(=φop(k))
FLAFBASE
+FLAFADP
Z-1
30h
ud(k-1)
σdud(k-1)
30b
σdud(k)
Σ:INTEGRATOR
30c